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INTELLECTUAL CAPITAL AND INNOVATION: A COMPARISON BETWEEN HIGH TECHNOLOGY AND LOW TECHNOLOGY FIRMS

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Abstract

Marta Buenechea Elberdin
Intellectual capital and innovation: A comparison between high technology and low technology firms
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The turbulent and challenging environment in which companies operate has contributed to the increasing interest of researchers to find new ways of innovating. Innovation essentially involves utilising knowledge resources for the creation of new knowledge assets (Nonaka & Takeuchi 1995; Tidd & Bessant 2009). Intellectual capital (IC) and innovation are intrinsically related because IC brings together all the knowledge-related resources that a company owns or manages for achieving sustainable competitive advantages (Youndt et al. 2004). Indeed, there is widespread support for IC as a relevant antecedent of innovation (Subramaniam & Youndt 2005; Wu et al. 2007; Hsu & Fang 2009; Martin-de-Castro et al. 2013a).

The studies listed above that focused on the relationship between IC and innovation have expanded the literature in the field by offering empirical evidence for a connection between IC and innovation, and by testing different linkages between both concepts. However, relevant research gaps remain. Since the seminal article by Subramaniam and Youndt (2005) on the IC antecedents of innovation was published over a decade ago, many other research papers have contributed to the field. A thorough literature review that analyses the past, current and potential future research paths of the IC–innovation literature was therefore needed. This comprehensive review revealed that the traditional IC framework composed of human, structural and relational capital (Sveiby 1997; Bontis 1998) is still widely applied in research works. However, as the environment and inner workings of companies might have changed in the last 20 years, there is likely a need to revise and update the knowledge resources currently operating in companies. In addition, researchers maintain that companies with different levels of technological sophistication manage knowledge of differing characteristics (Nelson & Wright 1992; Schilling 2010; De Carolis 2014; Rosenbloom 2014); nevertheless, the literature review herein discovered that studies about the IC–innovation relationship have not considered the technology level of the companies. Another research gap refers to the fact that various types of innovation may require different combinations of IC components (Damanpour & Aravind 2006; Damanpour & Aravind 2012). However, literature on the IC-innovation relationship has not taken the type of innovation into consideration.

Consequently, this thesis analyses the influence of both traditional and new IC components on different types of innovation performance, distinguishing between high and medium-high technology companies and low and medium-low technology firms. Four publications have attempted to contribute to this aim. The first is a structured literature review (SLR) about the literature dealing with the IC–innovation relationship. This publication revealed certain research gaps, two of which (related to the IC components considered and to the technology levels of the companies) are also addressed in this thesis. Publications 2, 3 and 4 are empirical research papers that test various models

linking traditional and new IC components with various types of innovation performance in high technology (high-tech) and low technology (low-tech) companies. These empirical publications offer relevant contributions to the IC literature and practical guidelines for business managers.

Keywords: Intellectual capital, traditional and new components, innovation, technology level

Resumen

Marta Buenechea Elberdin
Capital intelectual e innovación: Una comparación entre empresas de alta y baja tecnología
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El entorno turbulento y exigente en el que operan las empresas ha contribuido al creciente interés de los/as investigadores/as por encontrar nuevos modos de innovar. La innovación implica esencialmente la utilización de recursos de conocimiento para la creación de nuevos activos de conocimiento (Nonaka & Takeuchi 1995; Tidd & Bessant 2009). El capital intelectual (CI) y la innovación están intrínsecamente relacionados dado que el CI aglutina todos los recursos relativos al conocimiento que una empresa tiene o gestiona para obtener ventajas competitivas sostenibles (Youndt et al. 2004). De hecho, hay un apoyo generalizado a la idea de que el CI es un antecedente relevante de la innovación (Subramaniam & Youndt 2005; Wu et al. 2007; Hsu & Fang 2009; Martin-de-Castro et al. 2013a).

Los estudios arriba enumerados que se centran en la relación entre el CI y la innovación han expandido la literatura en el área ofreciendo evidencia empírica de una vinculación entre el CI y la innovación, y testando distintas conexiones entre ambos conceptos. Sin embargo, hay importantes lagunas en esta área de investigación. Desde que hace más de una década fue publicado el artículo seminal escrito por Subramaniam y Youndt (2005) sobre los componentes del CI que preceden a la innovación, muchos otros artículos de investigación han contribuido a este campo de conocimiento. Era por lo tanto necesaria una rigurosa revisión de la literatura que analizara el pasado, el presente y las posibles vías de investigación futuras de la literatura sobre la relación entre el CI y la innovación. Esta exhaustiva revisión reveló que el marco conceptual tradicional del CI compuesto por el capital humano, estructural y relacional (Sveiby 1997; Bontis 1998) es todavía ampliamente utilizado en los trabajos de investigación. No obstante, dado que el entorno y el funcionamiento interno de las empresas pueden haber cambiado en los últimos 20 años, es probable que sea necesario revisar y actualizar los recursos de conocimiento que operan actualmente en las empresas. Además, los investigadores sostienen que las empresas con distintos niveles de sofisticación tecnológica gestionan activos de conocimiento que presentan características diferentes (Nelson & Wright 1992; Schilling 2010; De Carolis 2014; Rosenbloom 2014); sin embargo, la revisión de la literatura descubrió que los estudios sobre la relación entre el CI y la innovación no han considerado el nivel tecnológico de las empresas. Otra laguna en este campo de investigación se refiere al hecho de que varios tipos de innovación pueden requerir distintas combinaciones de componentes del CI (Damanpour & Aravind 2006; Damanpour & Aravind 2012). No obstante, la literatura sobre la relación entre el CI y la innovación no ha tomado en consideración el tipo de innovación.

En consecuencia, esta tesis analiza la influencia de los componentes tradicionales y nuevos del CI en distintos tipos de innovación, distinguiendo entre empresas de alta y media-alta tecnología, por un lado, y baja y media-baja tecnología, por el otro lado.

Cuatro publicaciones han tratado de contribuir a este objetivo. La primera es una revisión de la literatura estructurada (RLS) sobre la literatura que trata la relación entre el CI y la innovación. Esta publicación reveló ciertas lagunas en la investigación, dos de las cuales (relacionadas con los componentes del CI considerados y con los niveles tecnológicos de las empresas) son también abordadas en esta tesis. Las publicaciones 2, 3 y 4 son artículos de investigación empíricos que testan varios modelos vinculando componentes tradicionales y nuevos del CI con varios tipos de innovación, en empresas de alta y baja tecnología. Estas publicaciones empíricas contribuyen a la literatura sobre el CI y ofrecen guías prácticas para las personas que trabajan en el mundo empresarial.

Palabras clave: Capital intelectual, componentes tradicionales y nuevos, innovación, nivel tecnológico

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‘Walker there is no path, you make the path as you go’
(Antonio Machado)

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List of publications

This dissertation is composed by the following publications.

Publication 1: Buenechea-Elberdin, M. (2017). Structured literature review about intellectual capital and innovation. *Journal of Intellectual Capital, 18*(2), 262-285.

Publication 2: Buenechea-Elberdin, M., Kianto, A., & Sáenz, J. (2018). Intellectual capital drivers of product and managerial innovation in high-tech and low-tech firms. *R&D Management, 48*(3), 290-307.

Publication 3: Buenechea-Elberdin, M., Sáenz, J., & Kianto, A. (2017). Exploring the role of human capital, renewal capital and entrepreneurial capital in innovation performance in high-tech and low-tech firms. *Knowledge Management Research & Practice, 15*(3), 369-379.

Publication 4: Buenechea-Elberdin, M., Sáenz, J., & Kianto, A. (In press). Knowledge management strategies, intellectual capital, and innovation performance: a comparison between high- and low-tech firms. *Journal of Knowledge Management*.

Author's contribution

The following explains the author's contribution to each of the publications making up this thesis.

Publication 1: 'Structured literature review about intellectual capital and innovation'

The doctoral candidate was the sole author of this publication.

Publication 2: 'Intellectual capital drivers of product and managerial innovation in high-tech and low-tech firms'

The author made a significant contribution to the collection and analysis of the data, the development of the models, writing the paper and revising the paper during the journal review process.

Publication 3: 'Exploring the role of human capital, renewal capital and entrepreneurial capital in innovation performance in high-tech and low-tech firms'

The author made a significant contribution to the data collection, development of the framework, writing the paper and revising the paper during the journal review process.

Publication 4: 'Knowledge management strategies, intellectual capital, and innovation performance: a comparison between high- and low-tech firms'

The author made a significant contribution to the data collection, development of the framework, writing the paper and revising the paper during the journal review process.

1 Introduction

In the current age, 'opportunities come and go at light speed—blink and you've missed a billion-dollar bonanza' (Hamel 2000, p.7). Globalisation, constant changes, increasing and fierce competition, and rapidly progressing technology have dramatically altered the context in which companies operate (Tidd & Bessant 2009). Innovation is the necessary ingredient in the recipe for survival (Lee & Tsai 2005; Du Plessis 2007) because, by developing novelties, firms can gain and sustain competitive advantages (Tidd & Bessant 2009). Therefore, finding ways to enhance innovation is likely to benefit companies working in this turbulent environment.

Innovation essentially involves utilising knowledge resources to develop new knowledge assets in the form of products, services and processes, among others (Nonaka & Takeuchi 1995, p.56). As intellectual capital (IC) refers to the knowledge assets owned or governed by a firm to obtain sustainable competitive advantages (Youndt et al. 2004), IC has commonly been considered a major enhancer of innovation. The traditional framework of IC considers the knowledge resources accumulated in individuals working in the company (i.e. human capital); in a firm's databases, information systems and written procedures (i.e. structural capital); and in the networks of relationships among individuals working in the firm as well as between the firm and external key stakeholders (i.e. relational capital) (Bontis 1996; Sveiby 1997; Bontis 1998). In addition, an emerging trend in the literature expands this well-known three-component framework by adding other knowledge-related assets, such as entrepreneurial and renewal capital (Inkinen et al. 2017). Entrepreneurial capital is the combined effect of entrepreneurial competence and commitment and includes the ability to identify opportunities, show initiative, assume risks and make bold decisions (Erikson 2002), while renewal capital refers to the capacity to learn and to renovate the knowledge base (Kianto et al. 2010).

Literature addressing the IC–innovation relationship has already demonstrated that IC is a pertinent antecedent of innovation. Researchers including Subramaniam and Youndt (2005), Wu et al. (2007), Wu et al. (2008), Hsu and Fang (2009), Carmona-Lavado et al. (2010), Aramburu and Sáenz (2011) and Wang and Chen (2013) have analysed how one or several IC components exert an impact on the development of novelties, on the enhancement of incremental and radical innovative capabilities and on the generation of new ideas. Nevertheless, important research gaps remain that should be addressed. First, even though a seminal article about the relationship between IC and innovation was published in 2005 (i.e. Subramaniam & Youndt 2005), and many other articles on the subject have since been published, there is no systematic review of the literature on this relationship. There is thus a lack of understanding about the past, current, and potential future research streams of the IC–innovation research field.

Further, a comprehensive review of the literature developed herein to address this research gap shed light on new gaps, such as the lack of studies on the IC–innovation linkage that include IC elements other than traditional ones and the need to consider the technological sophistication of companies when studying how IC affects innovation. The traditional IC framework was developed in the late 1990s and has, since then, been widely applied for testing the IC–innovation linkage. However, there have been deep changes in the world that seem to have altered the business context and the inner working of

companies. For example, the spread of global value chains, technological progress, the increasing role of the internet and changes in society (OECD 2015a; OECD 2015b) have created a more competitive environment in which producers and consumers have access to any company worldwide, where new and changing business opportunities that might enhance or destroy a competitive position have emerged and in which learning is an essential ingredient for understanding and dealing with the fast-moving competitive context. Therefore, why do IC components remain unaffected?

Regarding the technology level of companies Nelson and Wright (1992), Schilling (2010), De Carolis (2014) and Rosenbloom (2014) suggested that knowledge greatly differs between high- and low-tech companies; hence, the linkage between knowledge resources (i.e. IC) and innovation is also expected to work differently. Nevertheless, literature on the IC–innovation relationship has commonly omitted the influence of this contingency variable. Finally, as different types of innovation present varying characteristics (Damanpour & Aravind 2006; Damanpour & Aravind 2012), it is likely that IC antecedents differ from one innovation type to another. However, existing literature dealing with the way IC influences innovation has rarely considered variations in this linkage depending on the type of innovation.

Therefore, this dissertation analyses the influence of traditional and new IC components on different types of innovation performance, distinguishing between high and medium-high technology companies and low and medium-low technology firms. By addressing the identified research gaps, this study expects to contribute to academic research in the fields of IC and the IC–innovation linkage, and to business practitioners struggling to excel in innovation in a resource constrained environment.

1.1 Background

This dissertation is embedded in the field of Strategic Management, which is devoted to understanding company performance and the key factors in strategic choice (Grant 1996). In particular, the study is built into the resource-based view (RBV) of the firm (Wernerfelt 1984) that links companies' internal characteristics and their achieved performance (Barney 1991). The RBV considers resources as being heterogeneous and imperfectly mobile among companies (Barney 1991; Peteraf 1993); thus, all firms do not possess the same types of assets, and such assets are rarely transferred among companies. In addition, resources must fulfil certain characteristics to be sources of superior performance. Barney (1991) defined the VRIN model for the selection of assets which entails that only Valuable, Rare, Imperfectly imitable, and Non-substitutable resources should be considered as potential sources of competitive advantage.

The VRIN model evolved into the VRIO model (Barney 1995), switching Non-substitutable to Organisation. Barney (1995) considered that as imitation could be achieved by substituting resources, the Imperfectly imitable characteristic encompasses the Non-substitutable one. Given that 'to fully realize this potential [the potential of valuable, rare and imperfectly imitable resources], a firm must also be organized to exploit its resources and capabilities' (Barney 1995, p.56) the Organisation characteristic was added. This last characteristic of the VRIO model includes those complementary assets that support the firm in fully harnessing the potential of valuable, rare and imperfectly imitable resources (Barney 1995). As Organisation does not refer to assets

with the potential of being sources of sustainable competitive advantages but to resources that complement the previous ones, this study uses the VRIN model. Among the range of assets that might fulfil the VRIN model, knowledge has a prominent role, thus leading to the creation of the knowledge-based view (KBV) of the firm.

The KBV of the firm regards knowledge as the primary resource for gaining sustainable competitive advantages; it is thus an extension of the RBV focused on one specific asset (Grant 1996). In line with the KBV, managers must focus on producing, acquiring, retaining and utilising knowledge (Spender 1996). Even though there are different types of knowledge – i.e. information and know-how, declarative and procedural knowledge, know-how and know-why (Kogut & Zander 1992), and tacit and explicit knowledge (Polanyi 1966; Nonaka & Takeuchi 1995) – the identification and measurement of knowledge entities needs to be more specific. This greater specificity and more detailed understanding is offered by the intellectual capital view (ICV) of the firm.

ICV is a mid-range theory that focuses on three specific knowledge assets (i.e. traditional IC components) to narrow the wide approach of RBV (Reed et al. 2006). Similar to the KBV, this mid-range theory attempts to explain a firm's value by means of its knowledge assets (Reed et al. 2006). However, ICV focuses on 'the stocks and flows of knowledge capital' (Reed et al. 2006, p.869) rather than on how a company utilises its knowledge-management tools (Reed et al. 2006).

Figure 1 represents the evolution from RBV to ICV.

RBV	
Main idea: A company's inner assets that fulfil the VRIN model are sources of sustainable competitive advantages.	*Remark:* Knowledge is the resource that best fulfils the VRIN model.

⇩

KBV	
Main idea: Knowledge is the main source of sustainable competitive advantage.	*Remark:* A lack of specificity concerning the identification and measurement of knowledge entities.

⇩

ICV
Main idea: IC components (i.e. human, structural and relational capital) are the main knowledge-related resources.

Figure 1: From RBV to ICV.

1.2 Research gaps, main objective and research sub-questions

This dissertation addresses four relevant research gaps found in the field on the relationship between IC and innovation. These refer to the lack of a literature review examining the linkage between IC and innovation (RG1), the need for a deeper understanding about the influence of the technology level of the firm and the type of

innovation on the IC–innovation relationship (RG2 and RG3) and the need to learn more about the interactions between traditional and new IC components when influencing innovation performance (RG4).

The first research gap (RG1) relates to Subramaniam and Youndt's seminal article published in 2005 regarding the influence of traditional IC components on incremental and radical innovative capabilities. Many other articles followed this attempt to understand the IC antecedents of innovation. These papers made different choices concerning such things as the IC component or components that should be studied, the type of innovation to focus on and the methodology applied (i.e. Menor et al. 2007; Wu et al. 2007; Wu et al. 2008; Leitner 2011; Carmona-Lavado et al. 2013; Martin-de Castro et al. 2013b). Some reviews of the literature addressed IC and the IC antecedents of performance. Dumay, Guthrie and Puntillo (2015) analysed the public sector IC literature and Ferenhof, Durst, Bialecki and Selig (2015) examined existing models for IC measurement and classification. Inkinen (2015) focused on the influence of IC on performance and Moustaghfir (2009) investigated the impact of IC on sustainable competitive advantage. Nevertheless, former reviews have failed to specifically examine the IC–innovation relationship. Consequently, the first objective of this dissertation is to provide a review and critique of the empirical literature addressing the relationship between IC and innovation and to frame the future for this research field.

This literature review uncovered several research gaps, two of which (related to the sophistication of technology and to the range of IC components) are addressed in this dissertation. With respect to technological sophistication (RG2), there is wide consensus that it affects the type of knowledge assets managed by companies (Nelson & Wright 1992; Schilling 2010; De Carolis 2014; Rosenbloom 2014); thus, the influence of knowledge resources (i.e. IC) on innovation will be also altered. In addition, the aforementioned review of existing literature supports researchers' claim for a contingency approach to the study of the IC antecedents of innovation (Subramaniam & Youndt 2005; Reed et al. 2006) as it showed that technology level and other firm characteristics affect the IC–innovation linkage.

High-tech companies deal with increasingly complex knowledge (Schilling 2010), which remains mainly in its tacit form (Nelson & Wright 1992; Rosenbloom 2014) and should be frequently renewed (De Carolis 2014). Therefore, it is likely that high-tech firms require, for instance, highly qualified and skilful employees (i.e. human capital) and strong abilities for learning and renewing the companies' knowledge bases (i.e. renewal capital). By contrast, low-tech companies are characterised by simple, explicit and less frequently renewed knowledge (Nelson & Wright 1992; Schilling 2010; De Carolis 2014; Rosenbloom 2014). It follows that low-tech firms are likely eager to build well-developed databases and information systems (i.e. structural capital). However, existing literature has seldom examined technological sophistication and has never compared high- and low-tech enterprises in this regard. Consequently, the second objective of this thesis is to determine whether and to what extent technology level influences the relationship between IC components and innovation performance.

Another research gap tackled in this dissertation refers to how differences ingrained in various types of innovation influence their respective antecedents (RG3). For instance,

while product/service innovation is expected to satisfy 'an external user or market need' (Damanpour & Aravind 2006, p.60), management innovations, which are more internal to each individual company, can be influenced by the extent to which policies and procedures are formalised (Damanpour & Aravind 2012). Consequently, it is likely that external relational capital will have a major impact on product/service innovation, whereas both structural and internal relational capital will play greater roles in the development of new management practices. Nevertheless, the extant literature has rarely explored how various innovation types benefit from different antecedents. Except for some pioneering works that have compared product, process and organisational innovation (Elsetouhi et al. 2015), and incremental versus radical innovation (Subramaniam & Youndt 2005; Wang & Chen 2013), this research stream remains untapped. Hence, the third objective in this dissertation determines whether and to what extent the type of innovation affects the linkage between IC and innovation performance.

Finally, regarding IC components (RG4), the literature review revealed a dominance of the traditional IC framework (Bontis 1996; Edvinsson & Malone 1997; Sveiby 1997; Bontis 1998) in the study of how IC influences innovation. While there can be no question about the value and usefulness of the traditional three-component framework, it was designed about 20 years ago within a different economic, technological and social context. Changes in society such as the spread of global value chains, the prominent role of the internet, fast technological advances and ageing have revolutionised the environment in which companies operate (OECD 2015a; OECD 2015b). Consequently, the business context suffers from cutthroat competition, firms and consumers both have easy access to any product or service located around the world, opportunities are constantly emerging and leaving the market and, thus, competitive advantages could be easily destroyed. Therefore, learning and entrepreneurial capabilities become crucial in this constantly changing environment. Hence, it is likely that firms have been forced to adapt their inner knowledge resources (IC components) to meet the requirements of this new environment.

However, the wide range of studies on the IC–innovation linkage commonly applied the traditional IC framework without considering the possibility of having other IC components (i.e. entrepreneurial and renewal capital) operating within enterprises today. For this reason, the last objective in this study is to analyse the influence of both traditional and new IC components on innovation performance and to examine the specific way those components interact with each other to generate innovation.

In sum, given the research gaps identified, the overall objective of this study is to analyse the influence of both traditional and new IC components on different types of innovation performance, distinguishing between high and medium-high technology companies and low and medium-low technology firms. In accordance with this objective, the main research question stands as follows:

> How do traditional and new IC components affect innovation in companies with different levels of technological sophistication?

To answer this question, a comprehensive review of the literature dealing with the connection between IC and innovation was performed. The outcome of this review offers a detailed understanding and critique of the literature that focused on the IC–innovation

relationship and makes suggestions for future research lines. Thus, the following sub-questions are addressed:

> Q1. How is research for inquiring into the IC–innovation relationship developing? What is the focus of the IC–innovation relationship literature? What is the future for the IC–innovation relationship literature?

This literature review also gave rise to further research gaps in the IC–innovation field of research. One of these research gaps corresponds to the need to better understand the influence exerted by technology level on the relationship between IC and innovation. Accordingly, the next sub-question is posed:

> Q2. What is the impact of technology level on the relationship between IC and innovation performance?

In addition, literature about innovation argues that different types of innovation require various antecedents; thus, the connection between IC and innovation is expected to work differently among several innovation types. Accordingly, the following sub-question is addressed:

> Q3. What is the influence of the type of innovation on the relationship between IC and innovation performance?

Finally, the other research gap revealed by the literature review is the lack of studies on this subject that combine traditional and new IC components. In other words, the need to extend the traditional three-component framework to accommodate novel components and by doing so, adapting better to the current business environment. In consequence, the next sub-question is suggested:

> Q4. How do traditional (Q4a. human capital; Q4b. structural and relational capital) and new IC components interact with each other to generate innovation performance?

1.3 Structure

This dissertation begins by explaining the need for this study, positioning the thesis within the appropriate theoretical background and elaborating on the research gaps, objectives and research questions (see Table 1). Section 2 offers a detailed understanding about the theoretical background supporting the dissertation, and Section 3 presents the methodology applied and justifies the methodological choices made. Section 4 presents each of the four publications published and discusses the results obtained (see Table 1), and Section 5 answers the research questions posed, explains the theoretical and managerial contribution of the study and presents the limitations and future research directions.

Table 1: Research gaps, objectives, research questions, publications and conclusions

Main research gap	**Main objective**	**Main research question**
Lack of understanding about the way in which traditional and new IC components interact to influence different types of innovation performance and about the impact of technological sophistication on this relationship.	Analyse the influence of both traditional and new IC components on different types of innovation performance, distinguishing between high and medium-high technology companies and low and medium-low technology firms.	How do traditional and new IC components affect innovation in companies with different levels of technological sophistication?

Needs identified in previous publications[1]	**Research gap**	**Objective**	**Research sub-question**	**Publication and focus[2]**	**Conclusions**
---	RG1. Lack of a thorough review of the literature that deals with the IC–innovation relationship	O1. Provide a review and critique of the empirical literature dealing with the relationship between IC and innovation, and frame the future for this research field	Q1. How is research for inquiring into the IC–innovation relationship developing? What is the focus of the IC–innovation relationship literature? What is the future for the IC–innovation relationship literature?	Publication 1 'to review and critique the literature dealing with the relationship between intellectual capital (IC) and innovation, and to outline the future of this research field'.	Need for a contingency perspective in the study of how IC affects innovation More work is needed to understand the IC elements operating in firms Partial approaches to the study of innovation Disconnect between research, practice and policy
Contingency perspective	RG2. Literature fails to analyse the influence of technology level on the IC–innovation relationship RG3. Lack of understanding concerning which knowledge assets are the most important for different types of innovation	O2. Determine whether and to what extent technology level influences the relationship between IC components and innovation performance O3. Determine whether and to what extent the type of innovation affects the linkage between IC and innovation performance	Q2. What is the impact of technology level on the relationship between IC and innovation performance? Q3. What is the influence of the type of innovation on the relationship between IC and innovation performance?	Publication 2 'This article focuses on the intellectual capital antecedents of product/service and managerial innovation in high- and low-tech companies'.	Both technology level and type of innovation affect the influence exerted by IC on innovation performance Human capital is a major enhancer of innovation performance

(continued)

Table 1: Research gaps, objectives, research questions, publications and conclusions

Needs identified in previous publications[1]	**Research gap**	**Objective**	**Research sub-question**	**Publication and focus[2]**	**Conclusions**
Contingency perspective	RG2. Literature fails to analyse the influence of technology level on the IC–innovation relationship.	O2. Determine whether and to what extent technology level influences the relationship between IC components and innovation performance.	Q2. What is the impact of technology level on the relationship between IC and innovation performance?	Publication 3 ‘to deepen the current understanding of these human components of innovation activity across high-tech and low-tech companies’.	Technology level as a contingency variable affecting the IC–innovation linkage
Understanding IC elements	RG4. New IC components have been commonly omitted when studying the relationship between IC and innovation.	O4. Analyse the influence of both traditional (O4a. human capital) and new IC components on innovation performance, as well as the specific way those components interact with each other to generate innovation.	Q4. How do traditional (Q4a. human capital) and new IC components interact with each other to generate innovation performance?		Expand the traditional IC framework by demonstrating the relevance of EC and RNC
Relevant role of human capital					
Contingency perspective	RG2. Literature fails to analyse the influence of technology level on the IC–innovation relationship.	O2. Determine whether and to what extent technology level influences the relationship between IC components and innovation performance.	Q2. What is the impact of technology level on the relationship between IC and innovation performance?	Publication 4 ‘to analyse the complementary role of SC and RC, as codification and personalisation outcomes, in organisational renewal and innovation in high-tech and low-tech companies’.	Technology level as a contingency variable affecting the IC–innovation linkage
Understanding IC elements Important influence of renewal capital on innovation	RG4. New IC components have been commonly omitted when studying the relationship between IC and innovation.	O4. Analyse the influence of both traditional (O4b. structural and relational capital) and new IC components on innovation performance, as well as the specific way those components interact with each other to generate innovation.	Q4. How do traditional (Q4b. structural and relational capital) and new IC components interact with each other to generate innovation performance?		Importance of renewal capital as an IC component
					Conceptual link between knowledge management (KM) strategies and IC components

(1) This column shows the connections between each publication and the previous one/s.

(2) ‘Publication and focus’ contains quotations from the publications developed. Each quotation corresponds to the publication referred to in the same cell.

2 Theoretical points of departure

2.1 Resource-based view

The RBV of the firm, which 'examines the link between a firm's internal characteristics and performance' (Barney 1991, pp.100–101), is the main theory guiding the current study. The resource-based approach is embedded in the field of strategic management (Conner 1991; Peteraf 1993). As Conner (1991, p.122) clarified, 'the core notion of strategy as a fit between the internal competencies of the firm and external opportunities [Christensen, Andrews, Bower, Hammermesh, & Porter 1987] [fully] incorporates a resource-based perspective'. More precisely, the resource-based theory of the firm attempts to answer the following challenging question: Why are some firms able to implement strategies leading to sustainable competitive advantages and higher profits, while others are unable to do so? (Peteraf 1993; Grant 1996). In other words, why are some firms able to put in place successful strategies conducive to superior returns that no other current or potential competitor can implement?

Traditionally, environmental models that analyse the industry's opportunities and threats have been particularly popular in explaining sources of sustainable competitive advantage. One such model, the Porter's five forces framework, attributes differences in performance to disparities in the level of attractiveness of industries. However, Porter's model assumes that resources are highly mobile and homogeneously distributed across firms, thus establishing important limitations to the study of competitive advantage (Barney 1991). Indeed, 'empirical research has failed to support the link between industry structure and profitability' (Sáenz & Aramburu 2011, p.90). In turn, RBV assumes the heterogeneity and immobility of firm's strategic resources when analysing the sources of superior performance (Barney 1991; Peteraf 1993).

According to the RBV, resources are those strengths that allow the firm to develop strategies conducive to higher efficiency and effectiveness (Barney 1991), or 'anything which could be thought of as a strength or weakness of a given firm', or 'those (tangible and intangible) assets which are tied semi-permanently to the firm' (Wernerfelt 1984, p.172). These definitions all include important characteristics of resources and, thus, this dissertation defines resources as those tangible and intangible elements owned or managed by a firm with the intention of increasing its efficiency and effectiveness. Not all kinds of resources help a company achieve sustainable competitive advantages, but only do so those assets matching the VRIN model (Valuable, Rare, Imperfectly imitable and Non-substitutable; Barney 1991). Those resources that support strategies aiming at increasing efficiency and effectiveness (i.e. valuable), which are scarce among firms (i.e. rare) and are both hard to obtain (i.e. imperfectly imitable) and impossible to replace by companies lacking them (i.e. non-substitutable), contribute to achieving competitive advantages (Barney 1991). The VRIN model later evolved into the VRIO model (Barney 1995), which includes the new criterion, Organisation. Since 'Imitation can occur in at least two ways: duplication and substitution' (Barney 1995, p.53), the Non-substitutable criterion could be included as part of the Imperfectly imitable one (see Figure 2). Organisation refers to the degree to which a firm is prepared to exploit the full potential of its valuable, rare and imperfectly imitable resources and capabilities (Barney 1995).

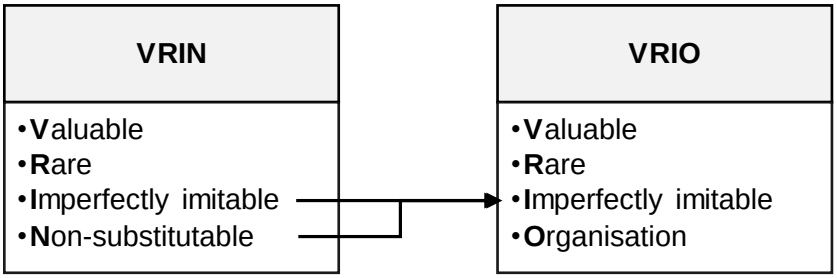

Figure 2: VRIN and VRIO

Even though the VRIO model is more complete than the VRIN framework, academic research typically prefers the latter. Thus, following the VRIN model and given that valuable, rare, imperfectly imitable and non-substitutable resources lead to sustainable competitive advantages (Barney 1991), the next question should be what those resources are. Priem and Butler (2001) argued that the way in which the RBV understands resources is too inclusive, making it hard to define effective practical orientations. Barney (2001, p.51), in turn, considered that 'Rather than limit its prescriptions to specific resources that can be identified, a priori, managers can apply resource-based logic to any resource whose value can be determined from the market context within which the resource is to be applied'. Although Barney (2001) maintained that inclusiveness improves prescriptive implications, being more specific is arguably more useful.

In this regard, intangible rather than tangible resources seem to be better in leading to superior returns as they are complex and firm-specific and are thus hard to imitate and purchase (Conner 1991; Sáenz & Aramburu 2011). As tangible resources can be exchanged in markets, keeping them scarce, hard to imitate and substitute is an almost impossible task. As Spender (1996, p.46) affirmed,

> So long as we assume markets are reasonably efficient and that competitive advantage is not wholly the consequence of asymmetric information about those markets or the stupidity of others, these rent-yielding capabilities must originate within the firm if they are to be of value.

Consequently, knowledge as a firm-specific intangible asset that is valuable, rare, imperfectly imitable and non-substitutable is the main resource that can help the company earn superior returns. The belief that knowledge is a company's central asset gave rise to a new body of literature known as the 'knowledge-based view'.

2.2 Knowledge-based view

KBV is considered an extension of the RBV since it singles out knowledge as the most relevant strategic resource (Grant 1996). Knowledge, or everything that is known, drives the company toward obtaining sustainable competitive advantages. As opposed to environmental models, RBV and KBV justify performance differences between companies with variations in internal assets. In both views, resources owned or managed by firms are major determinants of sustained competitive advantages. The main difference between them is that the KBV refines the RBV by focusing solely on knowledge and discarding other types of assets such as machinery, technology and capital. In fact, the focus on knowledge is the first assumption embraced by the KBV of the firm (Grant 1996). The second assumption refers to the idea that 'experts are (almost)

invariably specialists, while jacks-of-all-trades are masters-of-none' (Grant 1996, p.112). To create knowledge efficiently, people must have a deep understanding and high-quality management of specific knowledge domains (Grant 1996).

Knowledge has turned out to be 'the most important or 'strategic' factor of production, so managers must now focus on its production, acquisition, movement, retention and application' (Spender 1996, p.48); however, defining knowledge is far from easy. Nonaka and Takeuchi (1995) considered knowledge as 'justified true belief', which is the 'dynamic human process of justifying personal belief toward the 'truth'' (Nonaka & Takeuchi 1995, p.58). This definition raises two important concerns related to knowledge and the KBV of the firm: (1) Defining knowledge as 'justified true belief' is open and inclusive. Since the KBV adopts knowledge as the unique essential asset, questions about the characteristics and types of knowledge should be addressed. (2) If knowledge involves the justification of personal belief, which is the role of the firm? Is there organisational knowledge? The following paragraphs address these concerns.

Starting with the characteristics of knowledge, Grant (1996) pointed out three features to consider carefully when using knowledge, i.e. appropriability, capacity for aggregation and transferability. Contrary to other tangible resources, it is difficult to appropriate the value generated by knowledge. In addition, the capacity for aggregation of knowledge entities affects its transferability. In other words, the easier it is to aggregate knowledge elements, the more efficient it will be to transfer those aggregated entities both between and within the firm. (Grant 1996). These three characteristics pose challenges to the use and management of knowledge.

As many researchers have defined several types of knowledge, the literature distinguishes between information and know-how, declarative and procedural knowledge, know-how and know-why, individual and social knowledge, and tacit and explicit knowledge. Information and know-how are similar to declarative and procedural knowledge respectively; however, the latter is applied in the field of computer science (Kogut & Zander 1992). Information refers to facts, propositions and symbols, while know-how involves experience and practical skills (Kogut & Zander 1992). Information, unlike know-how, can be fully passed on, i.e. it can be transferred without losing integrity (Kogut & Zander 1992). Know-how and know-why represent respectively the ability to use and create something (Kogut & Zander 1992). 'Being taught the functional skills of how to do something [know-how] is different than being taught how to create it [know-why]' (Kogut & Zander 1992, p.391).

Finally, the distinction between tacit and explicit knowledge (under which individual and social knowledge will be described) deserves special attention. Tacit knowledge represents all that we know we cannot directly express: 'we can know more than we can tell' (Polanyi 1966, p.4), thus reflecting those apparently unexpressed aspects of knowledge. Tacit knowledge includes experience, intuitions and personal beliefs (Nonaka & Takeuchi 1995, p.8) that are difficult to communicate and transmit (Nonaka & Takeuchi 1995; Grant 1996). Explicit knowledge, on the contrary, 'can be expressed in words and numbers, and easily communicated and shared in the form of hard data, scientific formulae, codified procedures, or universal principles' (Nonaka & Takeuchi

1995, p.8). This form of knowledge is characterised by being easy to communicate (Grant 1996).

Therefore, knowledge of experience or tacit knowledge, and knowledge of rationality or explicit knowledge (Nonaka & Takeuchi 1995) represent two different modes through which knowledge can be created, shared, improved, communicated and applied. These two types of knowledge could also interact and complement each other to create new organisational knowledge. This interaction is the basis of the spiral of knowledge creation designed by Nonaka and Takeuchi (1995), which suggests four modes of knowledge conversion, i.e. socialisation (from tacit to tacit), externalisation (from tacit to explicit), internalisation (from explicit to tacit) and combination (from explicit to explicit). This knowledge spiral suggests two types of knowing entities: individual and social. Spender (1996) also defined four types of knowledge based on the implicit versus explicit dimension and the type of knowing entity. Therefore, automatic and conscious knowledge represent implicit and explicit knowledge at the individual level, and collective and objectified knowledge refer to implicit and explicit knowledge at the organisational level (Spender 1996).

Regarding the second issue, given that knowledge involves the justification of personal belief, it becomes challenging to define the role of the firm and to clarify the existence of organisational knowledge. A debate in the literature surrounds this issue: If knowledge is created by individuals and inextricably bound to human beings, then organisations are mere integrators of individuals and the knowledge they own. However, there might be knowledge elements such as organisational culture that go beyond the individual level and exist at the level of the firm. Therefore, what is the role of the firm in the creation and management of knowledge?

According to Grant (1996), the literature on the KBV of the firm conceives the company as an institution for knowledge acquisition and creation. Indeed, the knowledge spiral developed by Nonaka and Takeuchi (1995) explains the creation of organisational knowledge. Nonetheless, Grant's approach is different; he holds that companies 'exist as institutions for producing goods and services because they can create conditions under which multiple individuals can integrate their specialist knowledge' (Grant 1996, p.112). This perspective conceives the firm as a mere stove used for cooking dishes. The stove does not produce those dishes by itself but is at the service of the individuals who use it. A third standpoint acts as an intermediate perspective between the view of the company as a knowledge creator and as a knowledge integrator. This approach argues that 'organizations learn and have knowledge only to the extent that their members are malleable beings whose sense of self is influenced by the organization's evolving social identity' (Spender 1996, p.53). As both individuals and organisations create knowledge, it is hard to determine 'which is logically or temporally prior' (Spender 1996, p.53).

Even though the KBV offers interesting insights about the relevance and usefulness of knowledge, it lacks specificity concerning the identification and measurement of knowledge entities. In this regard, the IC View (ICV) offers a more detailed understanding. The ICV is an outgrowth of the KBV and is fully embedded in the RBV. Reed et al. (2006), who coined the term 'Intellectual Capital View', drew on pertinent literature in the field to discern that KBV and ICV 'both seek to explain the hidden

knowledge-based dynamics that underlie a firm's value', but 'differ in focus' because 'KBV is primarily interested in evaluating the effectiveness of a firm's use of knowledge-management tools as knowledge-generating mechanisms' while 'ICV's focus is on the stocks and flows of knowledge capital embedded in an organization' (Reed et al. 2006, p.869). Therefore, ICV is an upgraded version of the resources and capabilities approach that takes advantage of all the positive aspects of the two preceding theories, i.e. RBV and KBV, and solves many of their handicaps.

2.3 Intellectual capital view and intellectual capital

ICV is not a radically new theory totally unrelated to RBVs and KBVs. Instead, it is 'a specialization of the RBV' (Martin-de-Castro et al. 2011, p.659), complementary to the KBV (Reed et al. 2006) that focuses upon IC as the principal resource conducive to superior returns. ICV is presented as a kind of mid-range theory because it narrows down the wide RBV by selecting three specific resources to be the ones fostering sustainable competitive advantages (Reed et al. 2006). These type of theories 'fall somewhere between grand theories and empirical findings' (Bryman & Bell 2011, p.9). This mid-range theory fixes several deficiencies of the RBV raised by Priem and Butler (2001). First, ICV addresses the difficulties of providing guidelines to managers (Priem & Butler 2001) by concentrating solely on knowledge and it thus informs managers about the specific knowledge resources conducive to superior returns (Reed et al. 2006). Second, ICV offers a clear definition of competitive advantage that equates to 'the resource characteristics that allow a firm to outperform rivals in the same industry' (Reed et al. 2006, p.868). Third, regarding the tautology critique that implies defining outputs in terms of the inputs used (Priem & Butler 2001), ICV defines 'knowledge resources by their theoretical associations with competitive advantage and not by their empirical financial association' (Reed et al. 2006, p.868).

IC, which is the central element of the ICV, includes all the knowledge-related resources that a company owns or manages to obtain and sustain competitive advantages (Youndt et al. 2004). Bontis (1996, p.47) recognised that firms managing IC 'will have an advantage over their competition because they will know what knowledge is worth acquiring'. In a more radical way, Roos et al. (1997, p.5) stated that 'in the modern business world, the business imperative is to manage intellectual capital or die!'. The point here is that IC is not a mere resource available to companies, but rather it is at the core of every firm and must be carefully analysed and managed to get ahead of the competition.

The linkage established above between the RBV, KBV and ICV represents just a small part of the story about the origins of IC. The history behind IC is far more complicated and includes both academics and practitioners. Even though IC is nowadays a managerial concept, it was first coined by economist John Kenneth Galbraith in 1969 as the intellectual action or the intellectual property of a person (Roos et al. 1997; Roos 1998). It was not until the 1980s that the concept started gaining some relevance when business managers became aware about the gap between the firm value stated in financial reports and the market value of the firm; in short, financial reports were unable to account for invisible assets (Roos et al. 1997).

Practitioners quickly comprehended that invisible assets were not irrelevant resources but valuable treasures that need to be understood, measured and managed. Indeed, owing to the 'visible efforts' of business managers, and 'not scholarly articles', the IC concept grew in popularity in the early 1990s (Roos 1998, p.153). The central role of practitioners in the enhancement of IC is clear in what an executive expressed: 'Whereas knowledge management is a theory in search of practice, IC is a practice in search of a theory' (Roos 1998, p.151). In fact, back in 1996 and 1997, IC was considered 'an important topic that has rarely been studied or understood' (Bontis 1996, p.43) and a 'very new and unknown topic' (Roos et al. 1997, p.5).

Even though research into IC was almost non-existent at the beginning of the 1990s, studies on other related areas were already in place. Several research studies had focused on measuring the invisible assets of the firm, while others were devoted to managing knowledge and information as sources of sustained competitive advantage (Roos et al. 1997). Therefore, the creation of the concept of IC in the early 1990s implied, on the academic side, the fusion of these previously separated research streams (Roos et al. 1997). As 'IC is concerned with how better to manage and measure knowledge and other intangibles in the company' (Roos et al. 1997, p.7), research into IC evolved along these two research streams, and IC papers can thus be split into those concerned with measuring, accounting and reporting IC and those focused on creating, leveraging and managing IC to enhance a firm's value.

The present study is embedded in the second abovementioned research stream, i.e. creating, leveraging and managing IC, which has evolved through two main stages. The first stage, during the 1990s, was focused on developing measurement models of IC and it was clearly characterised by practitioners' influence. In the second stage, however, academics guided the field towards the study of the influence of IC on firm effectiveness, innovation or competitive advantage. (Martin-de-Castro et al. 2011). Figure 3 presents the theoretical background of this dissertation.

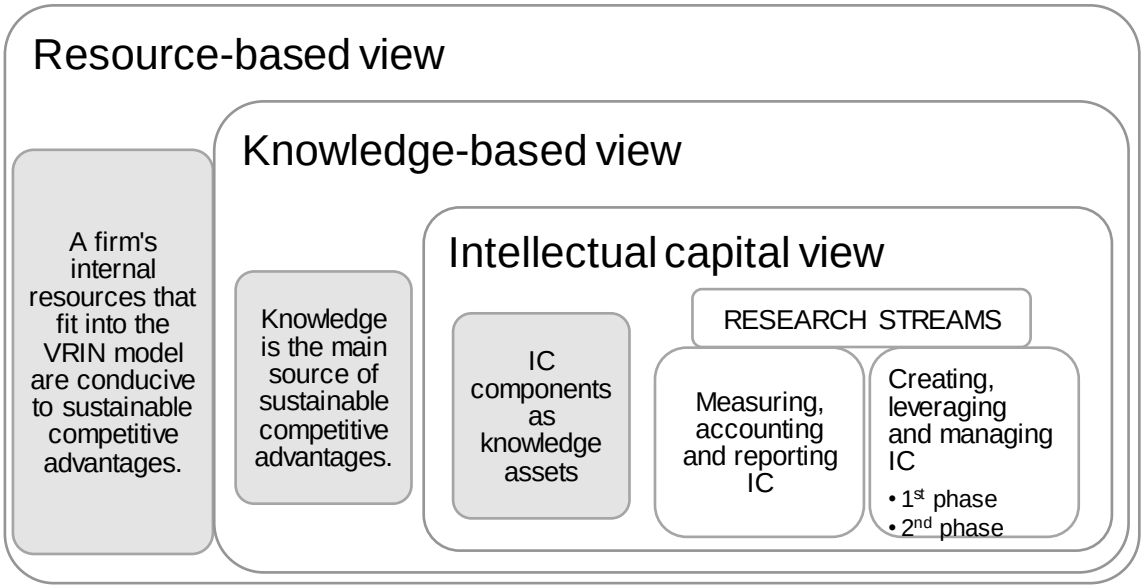

Figure 3: Theoretical background

This summary of the historical evolution of IC reveals that IC is not purely the result of the refinement of RBV and KBV, but it was concurrently developed during the 1980s and 1990s. Academic research has attempted to link IC with strategic management theory (Roos 1998). Roos and Roos (1997) and Roos (1998), who researched the origins of IC as developed by practitioners, recognised the connections between IC and the two well-known views from the strategic management theory, i.e. RBV and KBV. For example, Roos (1998, p.152) stated that 'IC may offer a complementary perspective to the efforts to bring forth a knowledge-based theory of the firm' and Roos and Roos (1997, p.415) claimed that 'some scholars in academia and in practice have focused on the implications of the resource and/or knowledge based view for the daily management of companies'. Hence, while IC is deeply ingrained in the RBV and KBV of the firm, it originally emerged from practitioners and was later connected to the strategic management theory.

Defining IC has turned out to be similar to describing the broad range of rainbow colours: multiple colours (definitions), each offering different insights into IC. However, providing a unique or unified definition is almost impossible (Martin-de-Castro et al. 2011). Sáenz and Aramburu (2011) argued that the wide range of definitions could be classified in two main groups, i.e. knowledge versus holistic perspectives, with the difference between both groups being the range of elements included. While the knowledge perspective defines IC as 'the sum of all knowledge firms utilize for competitive advantage' (Sáenz & Aramburu 2011, p.91), the holistic perspective expands the previous view including knowledge, other intangible resources and activities under the heading of 'IC' (Sáenz & Aramburu 2011, p.92). As an example, Reed et al. (2006, p.868) described ICV as dealing 'solely with knowledge' and Martín-de-Castro et al. (2011, p.650), summarising some definitions of IC, stated that 'IC includes the stocks or funds of knowledge, intangible assets, and ultimately intangible resources and capabilities'.

This distinction between the knowledge and holistic perspectives differs from the static versus dynamic distinction, according to which IC 'is viewed as a *stock*' (i.e. static), or it addresses 'the organisational capabilities to leverage, develop and change intangible assets for value creation' (i.e. dynamic) (Kianto 2007, p.344). The dynamic view of IC overlaps with knowledge management (KM) practices – 'the set of management activities that enable the firm to deliver value from its IC' (Kianto et al. 2014, p.365). However, with the exception of some attempts to connect IC and KM literatures, both research streams have been developed independently (Kianto et al. 2014). Without aiming to underestimate the holistic perspective and the dynamic view, the current research equates IC to knowledge-related resources and thus follows Youndt, Subramaniam and Snell's (2004, p.337) definition of IC: 'the sum of all knowledge an organization is able to leverage in the process of conducting business to gain competitive advantage'.

A broad consensus exists among researchers on the components or 'different expressions of firm's knowledge stocks' (Martin-de-Castro et al. 2011, p.653) that make up IC. Despite the different terms used to refer to each component, IC generally comprises human, organisational and both internal and external social capital (Reed et al. 2006). Bontis (1996; 1998), Sveiby (1997), Subramaniam and Youndt (2005) and Hsu and Fang (2009), among others, supported this three-component framework. This ''intellectual capital-based view of the firm' shows a new 'knowledge-based or intellectual-based'

framework for firm's competition, where 'knowledge worker' as well as 'knowledge-creating company' and 'sustained and trusted relationships' have a key role in today's business competition' (Martin-de-Castro et al. 2011, p.661). The following paragraphs describe the three IC components.

Human capital refers to the aforementioned knowledge workers and consists of their knowledge, skills and expertise (Schultz 1961; Subramaniam & Youndt 2005), as well as their attitudes and motivation (Bontis 1998). Human capital might include the creativity (Hsu & Sabherwal 2011), innovative character (Martin-de-Castro et al. 2013a) and other characteristics representative of knowledge workers. The great challenge of human capital is that even though it is 'the chief source of competitive advantage' (Roos & Roos 1997, p.413), firms do not own and fully control employees and their knowledge (Roos & Roos 1997; Roos et al. 1997).

Structural capital, or organisational capital, is 'an organization's institutionalized knowledge and codified experience stored in organizational memory devices such as patents, databases, manuals, routines, systems, cultures, and so on' (Youndt et al. 2004, p.346). Structural capital refers to the object and the system, which means the knowledge codified and the databases, technology and information systems utilised (Wu et al. 2007; Wang & Chen 2013). Contrary to human capital, structural capital is owned by the firm (Sveiby 1997). Edvinsson and Malone (1997) described structural capital as what is left in the company when its employees go home.

Relational capital, also called social capital, contains the knowledge stocks created, enhanced, shared and stored in the internal and external networks of relationships of the company. Relational capital may refer solely to the connections among employees and departments of the firm (Carmona-Lavado et al. 2010; Hsu & Sabherwal 2011) or could focus on the linkages between the company, and its customers, suppliers, governmental institutions and other pertinent partners (Bontis 1996; Sveiby 1997; Wu et al. 2007). Likewise, combinations of internal and external networks are popular among researchers (Subramaniam & Youndt 2005; Menor et al. 2007).

Furthermore, studies such as Kianto, Ritala, Inkinen and Vanhala (2013), Kianto, Ritala, Spender and Vanhala (2014), and Cesaroni, Baldo, Demartini and Paoloni (2015) have recently attempted to expand this traditional three-component framework with the aim of including other IC elements that are different from the traditional ones. This dissertation analyses two of these so-called 'new IC components', i.e. entrepreneurial and renewal capital. Entrepreneurial capital refers to the combination of entrepreneurial competence and commitment, which means the ability to identify and pursue opportunities and to obtain and coordinate resources, together with the intention, desire and compromise to act accordingly (Erikson 2002). Managerial attitude in firms oriented towards entrepreneurship is characterised by encouraging frequent and/or radical innovation, fostering an orientation towards competitors and boosting proactiveness and aggressiveness in dealing with high-risk decisions (Alegre & Chiva 2013; Fernández-Mesa & Alegre 2015).

Even though renewal capital is presented here as a new IC component, it has been part of the IC literature since the late 1990s. Edvinsson and Malone (1997) added the 'Renewal and Development Focus' to their Skandia Navigator to represent what the firm is currently

doing to prepare to take advantage of future opportunities. Sveiby (1997) focused on measuring the degree of change of employee competence, internal structure and external structure. Roos et al. (1997) presented renewal as including all the elements that will influence future value but still have not shown that impact. In line with these works, renewal capital is defined as the 'actualized learning capability of the firm' (Kianto et al. 2010, p.309), which is the ability to learn and update the knowledge base (Kianto et al. 2010). Learning is required for renewing the knowledge base as new knowledge and skills should be acquired to change previous cognition and behaviour. Firms that compete in fast-moving environments should foster learning and knowledge renewal (Zollo & Winter 2002). In addition, those companies oriented towards learning usually present a deep commitment to knowledge renovation, a shared vision about the relevance of learning and an open-mind for embracing new knowledge (Li et al. 2010).

Figure 4 shows the IC framework applied in this dissertation.

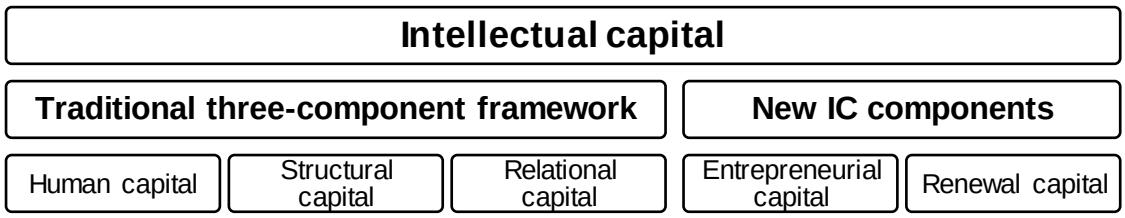

Figure 4: Traditional and new IC components

2.4 Intellectual capital and innovation

IC and innovation are both meaningful for company's success and they share knowledge as their pivotal point. While the previous section clarified the relevance of IC, the role of innovation is still not well defined. According to Tidd and Bessant (2009, p.5), 'those organizations that can mobilize knowledge and technological skills and experience to create novelty' are likely to gain competitive advantage. Hence, competitive advantage accrues from both the possession of specific internal resources – as argued by the RBV – and from the firms' ability to innovate. By means of innovation, companies can obtain strategic advantages such as offering novel products and services that competitors cannot imitate, taking first-mover advantages and rewriting the rules by creating novelties that make the former offerings obsolete (Tidd & Bessant 2009).

The abovementioned strategic advantages are necessary for surviving in the challenging environment in which companies operate. Hamel (2000, p.5) claimed that we are in the age of revolution in which change is discontinuous and thus, 'a company that is evolving slowly is already on its way to extinction'. A complex management environment, constant changes in customer preferences, fast-changing technology and short product lifecycles, among others, make innovation necessary for the survival of the fittest (Lee & Tsai 2005; Du Plessis 2007). Consequently, innovation is not an option for some companies with a sense of adventure, but a must for every business aiming to survive in the current globalised (1), constantly changing (2) and highly competitive environment (3), dominated by fast technological advances (4). The environment is:

(1) globalised because knowledge production is globally distributed and the internet has enhanced the use of virtual markets (Tidd & Bessant 2009);

(2) constantly changing, because the socioeconomic field, the legal requirements in any area and competitors' activities are continuously transforming (Tidd & Bessant 2009);

(3) highly competitive because other companies might always either imitate or improve what they have offered and firms must therefore be able to innovate better and faster than their competitors (Tidd & Bessant 2009); and

(4) dominated by fast technological advances since knowledge production has been accelerated giving rise to new technologies, devices, tools and any other technological development (Tidd & Bessant 2009).

Before examining the well-known IC–innovation relationship more closely, it is necessary to present relevant information about innovation, such as its definition and main typologies.

Innovation, which 'comes from the Latin *innovare* meaning 'to make something new'' (Tidd & Bessant 2009, p.16) is 'the creation of new knowledge and ideas to facilitate new business outcomes, aimed at improving internal business processes and structures and to create market driven products and services' (Du Plessis 2007, p.21). Innovation could also be seen as the 'process of turning opportunity into new ideas and of putting these into widely used practice' (Tidd & Bessant 2009, p.16), or as 'a new idea, method, process, or device that creates a higher level of performance for the adopting user' (García 2014, p.570). As can be seen, there are multiple definitions of innovation; Lee and Tsai (2005, p.328) and Crossan and Apaydin (2010, p.1165) affirmed that innovation has been approached from many disciplines. However, the definitions offered agree on two crucial points: (1) innovation always refers to the creation of something new (Sáenz & Aramburu 2011, p.89) and (2) innovation involves 'the development and exploitation aspects of new knowledge, not just its invention' (Tidd & Bessant 2009, p.16), and it thus embodies the final commercialisation stage.

In this dissertation, innovation is defined as the creation, development and commercialisation of new products, services, production processes, management and marketing practices, and business models. This definition emphasises different types of creations, which follow the classification suggested in the Oslo Manual (OECD & Eurostat 2005). Although there are many other typologies of innovation, including technological versus administrative, incremental versus radical, and disruptive versus sustaining (Garcia & Calantone 2002; García 2014), this study adheres to the proposal of the Oslo Manual since it is a worldwide recognised manual for innovation measurement and management, and the innovation taxonomy is inspired in Schumpeter's (1983) theory of innovation. Besides, as each type of innovation presents its own idiosyncrasy, distinguishing and understanding the specificities surrounding the various taxonomies of innovation is 'necessary for understanding the innovation adoption behavior in organisations, as well as for developing theories of innovations' (Damanpour 1987, p.676).

According to the Oslo Manual (2005), product/service innovation 'is the introduction of a good or service that is new or significantly improved with respect to its characteristics or intended uses' (p. 48); process innovation refers to 'the implementation of a new or significantly improved production or delivery method' (p. 49); marketing innovation 'is

the implementation of a new marketing method involving significant changes in product design or packaging, product placement, product promotion or pricing' (p. 49); and organisational innovation embodies 'the implementation of a new organisational method in the firm's business practices, workplace organisation or external relations' (p. 51). Instead of referring to the broad term 'organisational innovation', this dissertation divides it into managerial and business model innovation. The development of new management practices includes what the Oslo Manual refers to as the creation of new business practices, while innovations in workplace organisation and external relations, in conjunction with any other aspect related to the way the firm creates and captures value, is considered to come under business model innovation.

Innovation and knowledge are intrinsically linked. Knowledge is both the necessary input and the consequent output of the innovation process; that is, companies use knowledge to develop innovations that result in the creation of new knowledge (Nonaka & Takeuchi 1995, p.56). According to Tidd and Bessant (2009, p.37) 'Innovation is about knowledge – creating new possibilities through combining different knowledge sets'. This dissertation follows the literature in the IC field that places considerable attention on the study of knowledge as an antecedent of innovation, rather than the other way around. Accordingly, IC (i.e. knowledge stocks) owned and/or managed by companies influence innovation (Subramaniam & Youndt 2005; Wu et al. 2008; Hsu & Fang 2009; Carmona-Lavado et al. 2010; Cabello-Medina et al. 2011; Hsu & Sabherwal 2011; Martin-de Castro et al. 2013b).

Despite the large number of studies disentangling the IC–innovation connection – each one applying a broad range of IC components and related combinations, innovation types and methodologies – no comprehensive examination of the past, present and future of this research field exists. The lack of a thorough review makes it hard to understand what has been done and what remains to be done to the well-known IC–innovation relationship. The following paragraphs offer a greater insight into the way IC components (i.e. human, structural, internal relational, external relational, entrepreneurial and renewal capital) exert an impact on the creation of new developments.

Regarding human capital, people are the necessary ingredient for any new development. Knowledge, which is the main antecedent of innovation, is essentially related to individuals (Nonaka & Takeuchi 1995, p.58). Innovation is therefore a human activity, that is, individuals rather than machines, devices or any other tool lead the development of innovations. Researchers have widely recognised the relevance of human capital as a source of innovation, since knowledgeable, skilful and creative employees, who are experts in their field and the best in the industry, that have the necessary training and new and unique ideas, are the ones capable of developing successful new creations (Hsu & Fang 2009; Hsu & Sabherwal 2011; Carmona-Lavado et al. 2013; Elsetouhi et al. 2015).

Structural capital differs from human capital because it is not always a necessary ingredient in the innovation recipe; however, it supports the art of creating new developments by offering what could be named as 'the knowledge tool-box' of the organisation. Structural capital enhances innovation because it makes it easy to access and apply codified knowledge accumulated in databases and information systems, and it also provides technology to integrate various work processes (Wu et al. 2007; Wang &

Chen 2013). Therefore, as the tool-box of the organisation, structural capital offers an easily accessible knowledge base, information systems, procedures and technology to support the cooperation and development of business operations.

Innovation is a complex activity that requires expanding an individual's knowledge to integrate what others know. In other words, internal and external relational capital both become highly valuable for the successful creation of innovations. As Subramaniam and Youndt (2005, p.459) held, 'innovation is fundamentally a collaborative effort', and thus the knowledge embedded in the relationships maintained among employees and between employees and other institutions affects innovation. Internal communication among managers and among employees help to share ideas, concepts and other knowledge entities that foster the co-creation of innovations (Carmona-Lavado et al. 2010; Delgado-Verde et al. 2014). Moreover, knowledge contained in relationships with customers, suppliers, universities, research institutions, governmental institutions and other strategically relevant partners is pivotal for the development and commercialisation of the created novelties (Chen et al. 2015; Han & Li 2015).

Even though innovation is about entrepreneurship (Tidd & Bessant 2009, p.5), the literature disentangling the IC–innovation linkage has not yet included entrepreneurial capital. Therefore, the entrepreneurial literature is addressed to understand this relationship. Tidd and Bessant (2009, p.5) argued that the 'skill to spot opportunities and create new ways to exploit them is at the heart of the innovation process'. In a similar vein, Lumpkin and Dess (1996) and Wong (2014) linked specific characteristics of entrepreneurial capital with superior innovation. Innovativeness, or the 'tendency to engage in and support new ideas, novelty, experimentation, and creative processes' (Lumpkin & Dess 1996, p.142) encourages employees 'to think differently and do things differently' (Wong 2014, pp.231–232). In addition, as 'the market potential of innovative products is highly uncertain' (Wong 2014, p.232), the capacity to assume risks becomes pertinent for innovation. Moreover, the tendency towards 'seizing initiative and acting opportunistically in order to "shape the environment," that is, to influence trends and, perhaps, even create demand' (Lumpkin & Dess 1996, p.147) – proactiveness – is a major enhancer of innovation (Wong 2014). Overall, innovativeness, risk taking and proactiveness, which form part of entrepreneurial capital, help the company to abandon routine and comfort zones in favour of advancing, visualising, seizing and executing valuable opportunities that are translated into commercialised innovations.

Finally, renewal capital – the ability to learn and renovate the knowledge base (Kianto et al. 2010) – facilitates corporate renewal and technological advances (Bueno et al. 2010). The seminal work by Edvinsson and Malone (1997, pp.35–36) defined 'innovation capital' as 'the renewal capability and the results of innovation'; thus, establishing a connection between both concepts. As learning is a requisite which enables knowledge renewal, we could focus on the linkage between learning and innovation. Firms oriented towards learning are more susceptible to trying new ideas and ways of doing, adopting creative operation methods and developing new products and services (Calantone et al. 2002; Keskin 2006). In other words, learning-oriented companies are also innovation-oriented. The process of acquiring, distributing, interpreting and accumulating knowledge (i.e. organisational learning) fosters the creation of products, processes and administrative

procedures (Jiménez-Jiménez et al. 2008; Jiménez-Jiménez & Sanz-Valle 2011), and individual- and organisational-level innovation performance (Wang & Ellinger 2011).

The preceding paragraphs have presented evidence from the literature about the individual linkages between each IC component and innovation; however, the IC–innovation relationship is much more complex. IC components are 'complementary resources' (Reed et al. 2006, p.869) that present 'interdependencies' in their 'creation, development and leveraging' (Youndt et al. 2004, p.338; Carmona-Lavado et al. 2013, p.134). Therefore, 'compartmentalization of the components of intellectual capital may lead to simplification, which reduces its potential to explain the success of innovation activities' (Carmona-Lavado et al. 2013, p.134).

For that reason, many research articles about the IC antecedents of innovation create complex models in which IC elements interact with each other when influencing innovation. For example, social capital has been connected to human capital to analyse its influence on innovative performance (Cabello-Medina et al. 2011), and human capital has been linked to organisational capital (Elsetouhi et al. 2015), customer capital (Chen et al. 2014), and structural capital and relational capital (Wu et al. 2007; Hsu & Fang 2009) when studying its impact on innovation. Nevertheless, innovative combinations of IC stocks that integrate traditional (human, structural, internal relational and external relational capital) and new components (entrepreneurial and renewal capital) are all but non-existent amid the studies addressing the impact of IC on innovation. Moreover, existing literature has a tendency towards reducing the human antecedents of innovation to individuals' skills, qualification, motivation and experience. Thus, broader approaches that capture the real essence of human action are commonly omitted.

In addition, considering that IC stocks are probably among the most 'personal' and context-dependent resources, it seems somewhat paradoxical to analyse the IC–innovation linkage without including certain characteristics of companies. The seminal article by Subramaniam and Youndt (2005) brought to the fore the need for a contingency approach when analysing how IC influences innovation. More precisely, they explained that the connection between IC and innovation is 'complex and contingent upon several multifaceted organizational actions and attributes' (Subramaniam & Youndt 2005, p.460). In the same vein, Reed et al. (2006, p.876) proposed that 'knowledge resources are best understood within the specific context in which they are developed'; that is, IC components will differ according to the industry in which the company operates. The size of the company, the industry to which it belongs, where it is located and its level of technological sophistication all seem to affect both IC and innovation (Nooteboom 1994; Hipp & Grupp 2005; Cohen & Kaimenakis 2007; Hofstede et al. 2010; Kianto et al. 2010; Schilling 2010; De Carolis 2014).

However, the debate over the contingency perspective has been poorly developed in the studies analysing the IC–innovation relationship. While research works have typically considered the size of the company and the industry to which it belongs as potential influences that should be kept under control, they have not analysed in depth how these variables might affect the IC–innovation linkage. Besides, some studies disentangling the IC–innovation relationship have focused on firms belonging to a specific industry (Subramanian 2012; Elsetouhi et al. 2015), location (Martin-de Castro et al. 2013b; Wang

& Chen 2013) or technology level (Martin-de-Castro et al. 2013a; Martin-de Castro et al. 2013b). However, these works fail to examine the effects that the industry, location and level of technological sophistication have on the IC–innovation linkage.

Focusing on the technology level of the firm, evidence in the literature suggests that the level of technological sophistication alters certain characteristics of knowledge (see Table 2). Firms operating in high-tech industries deal with 'Knowledge that has many underlying components, or many interdependencies between those components, or both' (i.e. complex knowledge) (Schilling 2010, p.33). Moreover, as 'technology is partly in books and mind, partly in the fingers and organization' (Nelson & Wright 1992, p.1954), tacit knowledge becomes even more relevant in high-tech companies (Nelson & Wright 1992; Rosenbloom 2014). In addition, high-tech industries present a high degree of technological dynamism, which forces firms operating there to renovate their knowledge bases quite frequently (De Carolis 2014). In sum, the knowledge present in high- and low-tech companies differs in terms of its complexity, tacitness and renovation pace, which should dramatically affect the way knowledge stocks (IC) enhance or hinder innovation. Unfortunately, the extant body of literature has largely neglected the distinction between high- and low-tech companies.

Table 2: Knowledge-related characteristics and technology level

	High-technology industries	**Low-technology industries**
Level of complexity	High	Low
Degree of tacitness	Higher	Lower
Pace of renovation	Faster	Slower

The innovation side of the relationship also presents remarkable features. According to Teece (1980), technological and administrative innovations differ in terms of the necessity to reassign corporate functions and responsibilities. Damanpour and Aravind (2012), in turn, argued that product/service innovations should satisfy clients' needs, while managerial innovations must improve companies' internal efficiency. These and other differences between types of innovation affect which knowledge-based antecedents are likely to be the most important enablers of innovation and determine how these knowledge stocks (i.e. IC components) should be connected among them. For instance, the greater relevance of customers to the development of new products could elevate external relational capital to a prominent role in the enhancement of product innovation. Investigating which IC stocks are more suitable for the promotion of each type of innovation and how the set of complex interactions should be established could be highly beneficial for maximising the use of IC. Nevertheless, apart from Elsetouhi et al. (2015), who compared the influence of IC on product, process and organisational innovation, and some authors' works on incremental and radical innovation (e.g. Subramaniam & Youndt 2005; Wang & Chen 2013), there has been little interest in this distinction.

Figure 5 presents the overall research model of this dissertation. As the linkage between IC and innovation has already been demonstrated, the study focuses on combining traditional and new IC components, exploring different innovation types and analysing the influence of the technology level. Some parts of the figure are not visible to show the approach of each article.

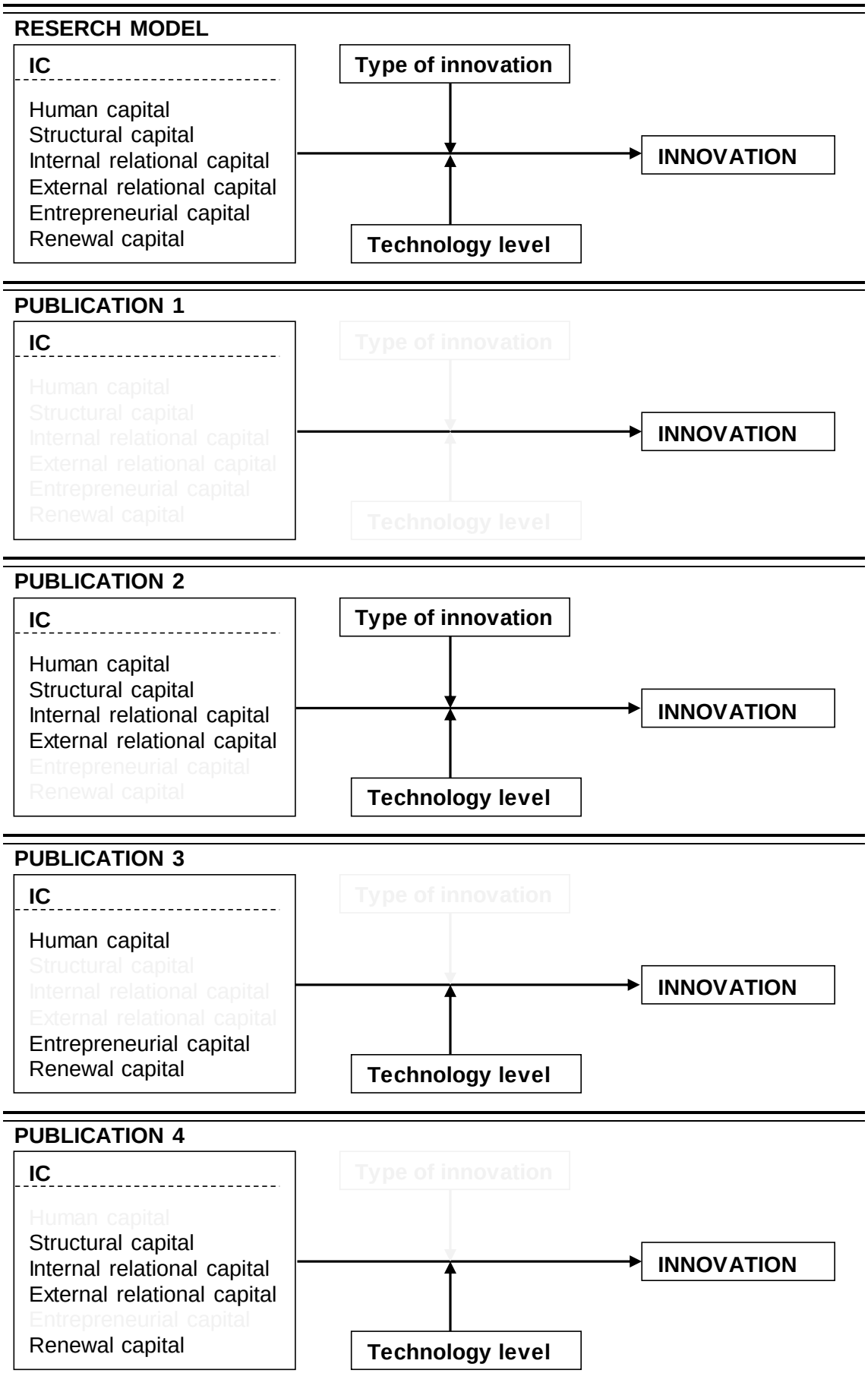

Figure 5: Overall research model

3 Research design and methods

3.1 Methodological considerations

This dissertation applies a quantitative research strategy because it 'emphasizes quantification in the collection and analysis of data' (Bryman & Bell 2011, p.26). This strategy belongs to the positivism epistemology, which claims to apply 'the methods of the natural sciences to the study of social reality' and in which the role of 'theory is to generate hypotheses that can be tested' (Bryman & Bell 2011, p.15). The relation between theory and research is therefore deductive, meaning the theory in the field is the point of departure and the arrival of the entire research process. Figure 6 shows how this dissertation adheres to the process of deduction.

The research process began with a review of existing literature in the field of IC, innovation and the linkage between both. This review followed both a traditional unstructured method in which the researcher attempted to acquire knowledge of the field and a more organised procedure through the SLR. The latter gave rise to the first article published in this dissertation. Based on the theory explored, three relevant research gaps were identified and hypotheses were defined for addressing them. A cross-sectional design, and in particular survey research, was selected as the framework for gathering and analysing the data (i.e. the research design) (Bryman & Bell 2011). In publications 2, 3 and 4, the collected data were analysed, the hypotheses were tested and the theory was revised accordingly.

1. Theory	Traditional review of the literature and SLR (Publication 1).
2. Hypothesis	RG2 and RG4 identified in the SLR and RG3 extracted from the literature.
3. Data collection	Research design: Cross-sectional design. Survey research. Research method: Questionnaire.
4. Findings	Obtained in publications 2, 3 and 4.
5. Hypotheses confirmed or rejected	Tested in publications 2, 3 and 4.
6. Revision of theory	Contribution to theory developed in publications 2, 3 and 4.

Figure 6: Process of deduction and the application to this dissertation. Adapted from Bryman and Bell (2011, p.11)

The following sections describe the two methods applied in this dissertation: SLR and survey research.

3.2 Structured literature review (SLR)

A SLR is used 'for studying a corpus of scholarly literature, to develop insights, critical reflections, future research paths and research questions' (Massaro et al. 2016, p.767). As the IC–innovation research field lacks a critical reflection about its evolution and potential research paths, developing a review of this type is worthwhile. The objective is thus to provide a review and critique of the empirical literature dealing with the relationship between IC and innovation and to frame the future of this research field.

Literature reviews in the management field are rife and many of them follow the principles of systematic literature reviews (Tranfield et al. 2003). Systematic literature reviews differ from SLRs in the rules set forth, which are more rigid in the SLR method (Massaro et al. 2016). The reasons supporting the selection of this method, instead of the popular systematic literature review, are threefold: (1) An SLR is recommended for unexperienced researchers who are diving into a research field for the first time (Massaro et al. 2016); (2) it 'complements traditional literature reviews because the approach helps to yield different outcomes that are defensible' (Massaro et al. 2016, p.769); and (3) it is 'attractive to researchers because they offer a history, some critique and outline the future research potential of particular domains' (Massaro et al. 2016, p.795).

3.2.1 Search strategy

To carry out the review, a straightforward definition of the characteristics of the target population was elaborated. Publications subject to be included were empirical in nature, since IC research should not be disconnected from practice (Petty & Guthrie 2000) and empirical publications provide valuable insights about business practice; published in peer-reviewed journals to guarantee a high level of quality; published between 2006 and 2015 because the field experimented a dramatic shift in 2005 when the seminal article written by Subramaniam and Youndt (2005) was published; focused on the IC–innovation linkage; and written in English because it is the official language of academia (see Figure 7).

Empirical publications	• IC research should be connected with practice. Empirical publications offer insights about practice.
Articles in peer-reviewed journals	• Guarantees high level of quality
Published from 2006 to 2015	• Seminal article published in 2005: 'The influence of intellectual capital on the types of innovative capabilities'.
Focused on the IC–innovation relationship	• This is the relationship explored in this study.
Written in English	• Official language of acadaemia.

Figure 7: Population for the SLR

The search (see Figure 8) was performed in various renowned academic databases, such as Scopus, EBSCO, Web of Knowledge (WOK) and Google Scholar, to avoid missing any relevant papers. An initial search (stage 1) was conducted in Scopus, EBSCO and WOK databases using the keywords 'intellectual capital' and 'innovation' in the title, abstract and keywords field. After analysing the titles and abstracts, the results were refined (stage 2) and it was verified that an additional search in Google Scholar was unnecessary (stage 3). Google Scholar Metrics lists top publications in several fields of study, among which the following list of categories was selected because they might relate to IC and/or innovation:

- business, economics and management

- business, economics and management (general)
- entrepreneurship and innovation
- human resources and organisations
- international business
- marketing
- strategic management
- tourism and hospitality

It was checked that all the journals included in these categories were already in the Scopus, EBSCO and/or WOK databases for the period 2006–2015 or were predatory journals according to the not presently active classification by Jeffrey Beall (https://scholarlyoa.com/).

In stage 4, owing to the limitations of the term 'innovation', which excludes 'innovative' and 'new product' among others, the search performed in stage 1 was repeated using the next search string: 'intellectual capital' AND 'innov*' OR 'new product' OR 'new service' OR 'new process' OR 'new management' OR 'new marketing' OR 'new market' OR 'new practice'. Most of the results obtained were already present in the first stage and were thus eliminated. Once the titles and abstracts of the remaining papers were checked, some extra articles were included in the list. This list was further analysed to check that all the journals listed were covered by Scopus, EBSCO and WOK for the selected period. As some years were missing years, a search of Google Scholar was conducted (but no new papers were found). In stage 5, the full texts of all the pre-selected papers were analysed and some were eliminated. As one person executed the search process, a verification round was deemed necessary and thus the list that emerged from stage 4 was revised once more (stage 6). The result did not change; hence, the final list included 40 articles. As shown in Table 3, excluding any of the selected databases would have resulted in missing relevant papers.

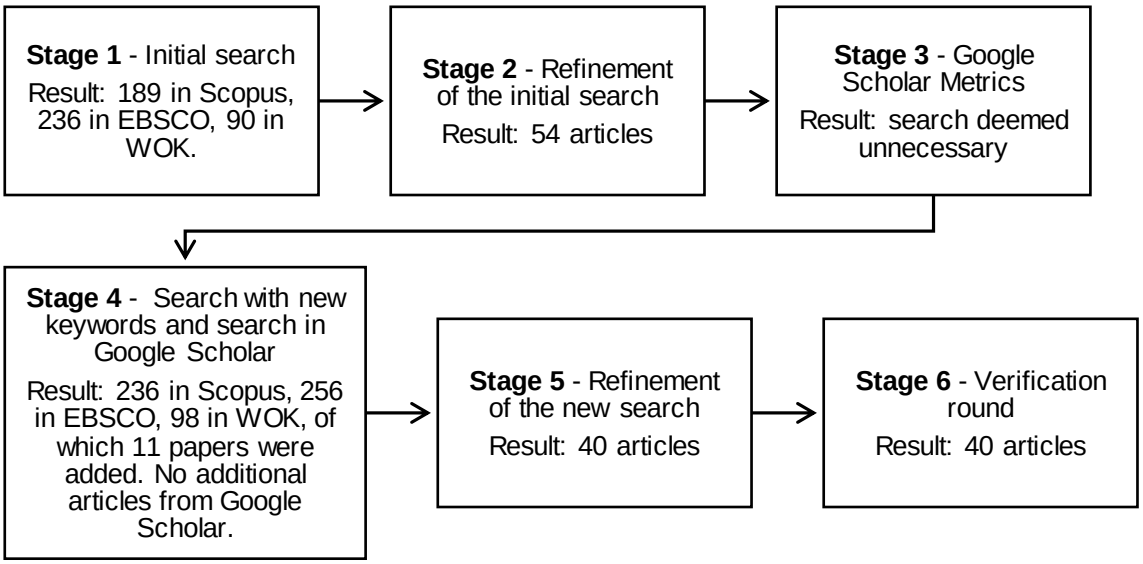

Figure 8: Search process

Table 3: Number of articles in the selected databases

	Scopus	EBSCO	WOK
Total number of articles	33	24	21
% over total articles	82.5%	60.0%	52.5%
Number of articles that exclusively belong to each database	8	5	1
% of articles that exclusively belong to each database	20%	12.5%	2.5%

3.2.2 Analytical framework

One of the most remarkable elements of the SLR method is using a framework for analysing the selected publications. This framework guides the analysis and is built through identifying 'units of analysis within selected papers' and their treatment 'as independent elements to be measured and analysed' (Massaro et al. 2016, p.783). In other words, the researcher should identify certain aspects (i.e. units of analysis or categories) within the field of research that require special attention. These aspects, which form the analytical framework, must be aligned with existing literature and respond to different needs found in it. For the purposes of this review, 16 categories (see Figure 9) were included in the framework and Nvivo 11 was used for the manual codification.

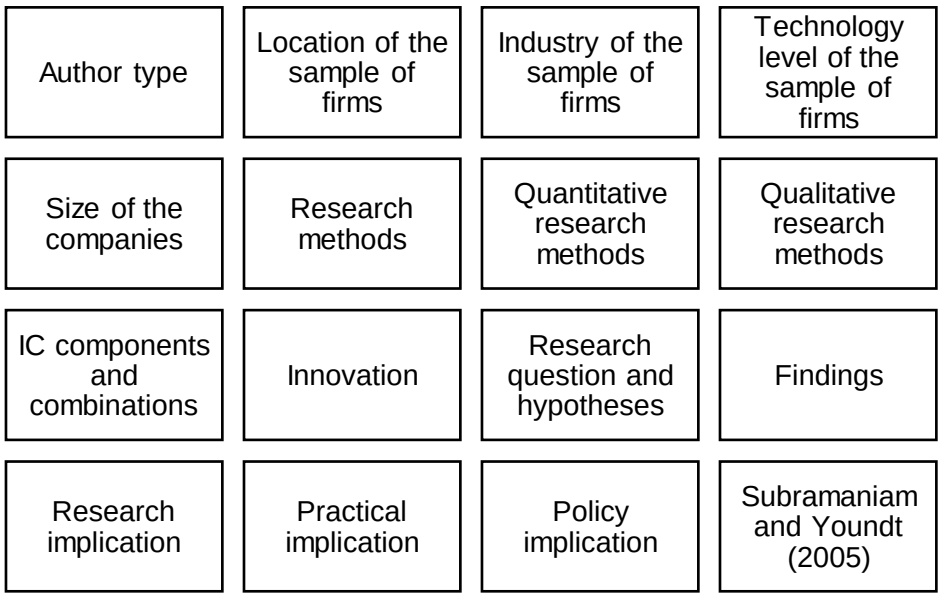

Figure 9: Categories of the framework – SLR

3.2.3 Validity and reliability

In terms of validity and reliability, the review presents positive aspects and deficiencies. The researcher attempted to keep the entire process from the conception of the idea to the publication of the article as unbiased as possible. To that end, the researcher followed the SLR procedure, which unlike traditional narrative reviews, 'use[s] a process that, through a set of explicit rules, offers less bias and more transparency' (Massaro et al. 2016, p.792).

The whole process is explicit and understandable, and the analytical framework was built from existing needs found in the literature to enable others to read and replicate the process. In addition, the articles analysed are peer-reviewed papers that should have overcome a strict reviewing procedure for achieving publication, and any predatory journal was excluded to avoid low-quality and ethically questionable publications. Moreover, the final stage of the search process verified that all the papers matching the established criteria have been selected, which compensates for the absence of another researcher taking part in the process.

However, it should be recognised that the researcher's preferences, thoughts, knowledge and skills influenced the review. According to Massaro et al. (2016, p.770), 'all literature reviews, including SLRs are biased due to the intervention of the researcher in simply choosing the body of literature to be reviewed'. Consequently, this SLR is not free from bias, thus leaving room for improvement in future publications.

3.3 Survey research

The quantitative methodology, rather than the qualitative approach, was considered the most appropriate for examining the relationship between IC and innovation performance in companies with varying levels of technological sophistication. By means of a qualitative methodology, the researcher makes 'a commitment to seeing the social world from the point of view of the actor' (Bryman 1984, p.77) and 'produce data which they often call 'rich' by which is meant data with a great deal of depth' (Bryman 1984, p.79). Therefore, qualitative methodology elaborates on the 'hows' and the 'whys' of social phenomena, which offers the researcher a deep understanding of the reality. This approach might be suitable for representing the tacit knowledge embedded in IC and the complexities ingrained in the term innovation, which accounts for a great variety of typologies.

By contrast, a quantitative approach regards the reality as being objective and external to the researcher (Bryman & Bell 2011, p.27) and is concerned 'with operational definitions, objectivity, replicability, causality, and the like' (Bryman 1984, p.77) as well as the generalisation of the results beyond the context in which the study was performed (Bryman & Bell 2011, p.163). Thus, the researcher's focus in quantitative studies is less on examining the specificities of the analysed phenomena and more on generalising the findings to other contexts. This implies that the sample size is far larger in quantitative than in qualitative studies.

For this study, it was considered that the research gaps identified could be better addressed by applying a quantitative methodology. There is a lack of previous research on the interactions among traditional and new IC components and their influence on innovation, as well as the way in which the IC–innovation linkage changes according to the level of technological sophistication and the type of innovation; thus, a first quantitative approach to these issues is highly beneficial. Although a question remains as to whether a survey can capture the real essence of the variables under study, many articles published in high-quality journals have used questionnaires to measure IC and innovation (e.g. Subramaniam & Youndt 2005; Wu et al. 2008; Hsu & Fang 2009; Delgado-Verde et al. 2011). Following a quantitative methodology, several exploratory models explaining the

linkage between both traditional and new IC components, and various types of innovation in high- and low-tech companies could be developed.

3.3.1 Sample and data collection

The population of this research encompasses Spanish firms with 100 employees or more, whose financial accounts were registered in the SABI database (*Sistema de Análisis de Balances Ibéricos*; System of Iberian Balance Sheet). SABI contains the annual accounts of around 2,500,000 Spanish and Portuguese companies. Of 1,289 firms initially identified, 700 were contacted by phone during the data collection period, which extended from October 2013 to February 2015. The researcher was in charge of collecting the data, and thus contacted companies by phone to explain the research project. The responses to the questionnaire were collected either by phone or email and the responses were registered in an Excel spreadsheet. Participants answered a structured questionnaire that will be described in subsection 3.3.2. A crucial aspect of the data collection process was confidentiality, which was guaranteed to every company that took part in the research.

Consistent with the aim of distinguishing between high and medium-high technology companies and low and medium-low technology firms, efforts were made to balance both technology levels in the final sample. The way of categorising companies into high- or low-tech was suggested by INE (*Instituto Nacional de Estadística*; Nacional Institute of Statistics) and followed the criteria set by the Organisation for Economic Cooperation and Development (OECD) and EUROSTAT. Industries belonging to high or medium-high technology levels (in this study, high-tech) present a higher level of R&D intensity, while those in low or medium-low technology levels (in this study, low-tech) have a lower R&D intensity (Instituto Nacional de Estadística (INE) 2001).

The final sample of companies comprises 180 firms (response rate of 25.71%), of which 86 (47.78%) belonged to high-tech industries and 94 (52.22%) were low-tech firms (see Table 4). As for the profiles of the respondents, 89.44% of participants held a responsible position in the firms they were representing, either as managing directors (3.89%), human resource managers (67.22%) or heads of other departments (18.33). The remaining participants (10.56%) were employees who did not occupy responsible positions.

Table 4: Sample composition

Industry	Frequency	Percentage
20 Manufacture of chemicals and chemical products	5	2.78%
21 Manufacture of basic pharmaceutical products and pharmaceutical preparations	3	1.67%
27 Manufacture of electrical equipment	3	1.67%
28 Manufacture of machinery and equipment n.e.c.	4	2.22%
29 Manufacture of motor vehicles, trailers and semi-trailers	14	7.78%
30 Manufacture of other transport equipment	2	1.11%
50 Motion picture, video and television programme production, sound recording and music publishing activities	3	1.67%
60 Programming and broadcasting activities	3	1.67%
61 Telecommunications	4	2.22%
62 Computer programming, consulting and related activities	35	19.44%
63 Information service activities	3	1.67%
72 Scientific research and development	7	3.89%
Medium-high and high-technology subtotal	**86**	**47.78%**
10 Manufacture of food products	15	8.33%
11 Manufacture of beverages	5	2.78%
12 Manufacture of tobacco products	1	0.56%
13 Manufacture of textiles	1	0.56%
14 Manufacturing of wearing apparel	1	0.56%
15 Manufacture of leather and related products	2	1.11%
17 Manufacture of paper and paper products	1	0.56%
18 Printing and reproduction of recorded media	1	0.56%
22 Manufacture of rubber and plastic products	4	2.22%
23 Manufacture of other non-metallic mineral products	2	1.11%
24 Manufacture of basic metals	6	3.33%
25 Manufacture of fabricated metal products, except machinery and equipment	7	3.89%
31 Manufacture of furniture	1	0.56%
32 Other manufacturing	1	0.56%
33 Repair and installation of machinery and equipment	1	0.56%
35 Electricity, gas, steam and air conditioning supply	1	0.56%
36 Water collection, treatment and supply	1	0.56%
41 Construction of buildings	1	0.56%
42 Civil engineering	2	1.11%
43 Specialised construction activities	1	0.56%
46 Wholesale trade, except of motor vehicles and motorcycles	3	1.67%
47 Retail trade, except of motor vehicles and motorcycles	1	0.56%
49 Land transport and transport via pipelines	8	4.44%
52 Warehousing and support activities for transportation	1	0.56%
55 Accommodation	3	1.67%
56 Food and beverage service activities	2	1.11%
58 Publishing activities	3	1.67%
70 Activities of head offices; management consultancy activities	2	1.11%

(continued)

Table 4: Sample composition

Industry	Frequency	Percentage
71 Architectural and engineering activities; technical testing and analysis	2	1.11%
74 Other professional, scientific and technical activities	3	1.67%
79 Travel agency, tour operator and other reservation service and related activities	1	0.56%
81 Services to buildings and landscape activities	2	1.11%
84 Public administration and defence; compulsory social security	1	0.56%
85 Education	1	0.56%
86 Human health activities	1	0.56%
87 Residential care activities	3	1.67%
88 Social work activities without accommodation	2	1.11%
Medium-low and low-technology subtotal	**94**	**52.22%**
Total	**180**	**100.00%**

3.3.2 Measures

Measures utilised in this dissertation were developed by a group of four researchers, led by Professor Aino Kianto, from Lappeenranta University of Technology (Finland) as part of an international research project entitled 'Intellectual Capital and Value Creation'. This project was funded by the Finnish Funding Agency for Innovation (TEKES). All measures shown in Table 5 are based on previous scales utilised in the field of IC and apply five-point Likert scales ranging from 1 (strongly disagree) to 5 (strongly agree). All IC components and innovation performance were considered 'reflective indicators' because the items belonging to each indicator reflect the variable; that is, the latent variable precedes the indicators.

Table 5: Questionnaire

Constructs and measures	Item wording	Sources
Human capital (reflective)		Bontis 1998; Yang & Lin 2009
HC1	Our employees are highly skilled at their jobs.	
HC2	Our employees are highly motivated in their work.	
HC3	Our employees have a high level of expertise.	
Structural capital (reflective)		Kianto 2008; Kianto et al. 2010
SC1	Our company has efficient and relevant information systems to support business operations.	
SC2	Our company has tools and facilities to support cooperation between employees.	
SC3	Our company has a great deal of useful knowledge in documents and databases.	
SC4	Existing documents and solutions are easily accessible.	

(continued)

Table 5: Questionnaire

Constructs and measures	**Item wording**	**Sources**
Internal relational capital (reflective)		Kianto 2008; Yang & Lin 2009
IRC1	Different units and functions within our company – such as R&D, marketing and production – understand each other well.	
IRC2	Our employees frequently collaborate to solve problems.	
IRC3	Internal cooperation in our company runs smoothly.	
External relational capital (reflective)		Kianto 2008
ERC1	Our company and its external stakeholders – such as customers, suppliers and partners – understand each other well.	
ERC2	Our company and its external stakeholders frequently collaborate to solve problems.	
ERC3	Cooperation between our company and its external stakeholders runs smoothly.	
Entrepreneurial capital (reflective)		Hughes & Morgan 2007
ENTCAP1	Risk-taking is regarded as a positive personal quality in our company.	
ENTCAP2	Our employees take deliberate risks related to new ideas.	
ENTCAP3	Our employees are excellent at identifying new business opportunities.	
ENTCAP4	Our employees show initiative.	
ENTCAP5	The operations of our company are defined by independence and freedom in performing duties.	
ENTCAP6	Our employees have the courage to make bold and difficult decisions.	
Renewal capital (reflective)		Hughes & Morgan 2007; Kianto et al. 2010; adapted from García-Morales et al. 2006
RENCAP1	Our company has acquired a great deal of new and important knowledge.	
RENCAP2	Our employees have acquired a great deal of important skills and abilities.	
RENCAP3	Our company can be described as a learning organisation.	
RENCAP4	The operations of our company can be described as creative and inventive.	

(continued)

Table 5: Questionnaire

Constructs and measures	Item wording	Sources
Innovation performance (reflective)	Compared to its competitors, how successfully has your company managed to create innovations/new operating methods in the following areas over the past year?	Weerawardena 2003
INNOPER1	Products and services for customers	
INNOPER2	Production methods and processes	
INNOPER3	Management practices	
INNOPER4	Marketing practices	
INNOPER5	Business models	

Control variables were added to avoid elements different from the ones analysed in this research affecting the results. Compared to large corporations, small firms are more agile in terms of innovation (Nooteboom 1994) and present different kinds of organisational practices (Cohen & Kaimenakis 2007). The nature of innovation changes from one industry to another (Lee 2005; Jiang et al. 2012), and IC and innovation both differ between manufacturing and service industries (Hipp & Grupp 2005; Kianto et al. 2010). Consequently, size – the natural logarithm of the number of employees – and industry – dummy variable that distinguishes between manufacturing and service industries – were included in publications 2, 3 and 4. Furthermore, publication 4 incorporates human capital as a control variable. Publication 4 did not analyse the influence of human capital on innovation performance; however, the relevance of human resources for innovation made it necessary to control them to guarantee that the results obtained are not influenced by the potential effect of human capital.

In terms of validity, as the questionnaire is part of an international research project, experts from each country assessed the items proposed for each construct. In this way, the content or measurement validity of the questionnaire was guaranteed. Moreover, as the questionnaire has been applied in several publications such as Cesaroni et al. (2015), Inkinen et al. (2015), Andreeva et al. (2017), Inkinen et al. (2017) and Sáenz et al. (2017), it is possible to claim that the questionnaire has been proved to be valid for measuring both IC and innovation.

The integrity of the conclusions (i.e. validity) was threatened by the risk of common method bias (Podsakoff et al. 2003). Common method bias might influence the results since the same person in each company answered the questionnaire, from which all the dependent and independent variables used in the study were obtained. However, the result of the Harman's one-factor test (Podsakoff & Organ 1986) showed that common method bias did not affect the results of the survey and does not therefore diminish the validity of the research.

Although the validity of the study is not compromised, it would have been highly advantageous to have more than one respondent per company. Information coming from different levels and areas of the organisation enriches the final picture of the firm. This shortcoming is partly offset by the fact that almost 90% of the participants held a position of responsibility in their companies, suggesting that they regularly take part in executive

committee meetings in which relevant information about main issues is shared and discussed. The respondents therefore have a general overview of the company to incorporate into their answers to the questionnaire.

3.3.3 Statistical analysis

The data collected using the structured questionnaire was analysed in the three empirical articles using SPSS software version 23 and structural equation modelling (SEM) based on partial least squares (PLS) – PLS-Graph software 3.0 (Chin & Frye 2003). SPSS was applied to conduct the descriptive analyses, and SEM was used to assess the validity and reliability of the measurement model and test the suggested hypotheses. These hypotheses described three types of relationships, i.e. direct impact, indirect impact by means of mediation or moderation effects. While the direct influence involves two variables, both the mediation and the moderation integrate three variables. In the case of mediation (see Figure 10), the influence of variable 'A' on variable 'B' is indirect by means of variable 'C'. In turn, moderation (see Figure 11) reflects that the direct relationship between variables 'A' and 'B' is stronger or weaker in the presence of variable 'C'. The following paragraphs explain the models built and the specific analyses conducted in each publication.

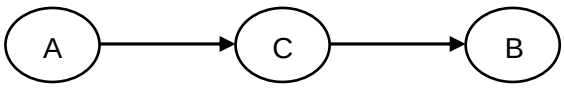

Figure 10: Mediation

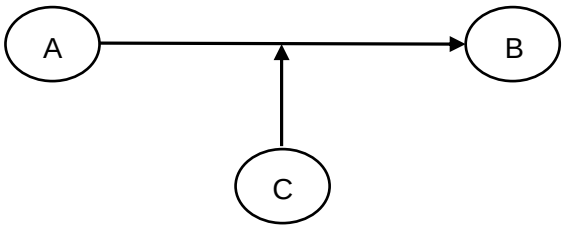

Figure 11: Moderation

The models developed in the three empirical publications attempt to represent different ways in which IC components could influence innovation performance in companies with varying levels of technological sophistication. In publication 2 (see Table 6), traditional IC components were linked to innovation performance. More precisely, human, structural, internal relational and external relational capital were directly connected with either product/service innovation or managerial innovation performance. The moderating role of technology level in the abovementioned relationships was also assessed, and both size and industry were included as control variables.

Publication 3 (see Table 6) tested a combination of traditional and new IC components. Human capital was regarded as an antecedent of both entrepreneurial and renewal capital, and entrepreneurial capital was considered prior to renewal capital. The three IC components (human, entrepreneurial and renewal capital) were directly connected to innovation performance. As in publication 2, the moderating role of the level of

technological sophistication was also tested, and both size and industry were deemed control variables.

In publication 4 (see Table 6), traditional and new IC components were again combined in a single model. Structural capital, and both internal and external relational capital were directly linked to renewal capital. These traditional components and renewal capital were also expected to directly influence innovation performance. Moreover, the moderation effects of the technology level were evaluated. Contrary to previous models, not only were size and industry considered control variables, but also human capital.

To test these models, descriptive analyses, SEM based on PLS and a multigroup analysis were performed in each publication. At the descriptive level, the analyses showed the degree of development of each indicator and each latent variable within each subsample, i.e. high-tech and low-tech firms. In these descriptive analyses, t-tests were executed to identify potential significant variations of values.

After that, SEM based on PLS was applied to evaluate the measurement model (Phase 1) and to assess the structural model (Phase 2). With regard to phase 1, as all indicators were considered reflective (see Table 5), the validity and reliability of the measurement model were evaluated using four types of tests, i.e. individual item reliability, construct reliability, convergent validity and discriminant validity. Individual item reliability shows the extent to which a particular item truly measures the latent variable to which it is connected. Indicator loadings should be above 0.707. Construct reliability refers to the extent to which all the indicators making up the same latent variable are really measuring the same construct (i.e. are highly correlated). Hence, construct reliability relates to the internal consistency of the indicators measuring each latent variable. For this to be deemed appropriate, the composite reliability of each variable should be higher than 0.8. Convergent validity shows whether a particular construct extracts a large amount of variance from its own indicators. For convergent validity to have adequate levels (i.e. to guarantee that each latent variable extracts more variance from each own indicators than from others), the average variance extracted (AVE) should be above 0.5. Discriminant validity refers to the extent to which constructs in a particular model are really measuring different phenomena. To calculate this, the diagonal elements of the correlation matrix between variables is substituted by the square root of AVE of each variable. If the square root of AVE is higher than the rest of the correlations in the same row and column, discriminant validity is preserved.

Regarding the results from the measurement model evaluation, in the case of publication 2, the four tests were overcome with some insignificant exceptions related to the loadings of few indicators. These indicators were kept in the models since the values were close to the acceptable limit. As for publication 3, the results obtained were above the threshold limits with the exception of some indicator loadings. While most of them are proximate to 0.707, one of them was not and was thus deleted. In the case of publication 4, apart from three indicator loadings that showed values just below the established limit, all parameters presented adequate values; thus, guaranteeing the validity and reliability of the measurement model.

In phase 2 (structural model evaluation), the strength of the research hypotheses and the predictive power of the model were examined. As for the research hypotheses,

bootstrapping techniques were utilised to test the strength of the relationships between variables, which were represented by the path coefficients. Following Falk and Miller (1992), the predictive power of the model was tested by checking the value of R^2. For a model to have predictive power, R^2 should be above 10%.

For moderation effects to be tested in each model, a multigroup analysis was carried out in each of the three publications to detect potential significant differences in the path coefficients between high-tech and low-tech firms. In addition, as some of the relationships between IC and innovation were non-significant in publication 2, some post-hoc analyses were performed to confirm whether they had no influence on innovation performance, or whether their impact was mediated by other variables in the model.

Table 6: Research question, publication, variables included and statistical analysis

Research question	**Publication and focus[1]**	**Variables included**	**Statistical analysis**
Q2. What is the impact of technology level on the relationship between IC and innovation performance? Q3. What is the influence of the type of innovation on the relationship between IC and innovation performance?	Publication 2 'This article focuses on the intellectual capital antecedents of product/service and managerial innovation in high- and low-tech companies'.	IC components: - Human capital - Structural capital - Int. relational capital - Ext. relational capital Product/service innovation Managerial innovation	- Descriptive analyses - SEM based on PLS - Multigroup analysis - Post-hoc analysis (mediation)
Q2. What is the impact of technology level on the relationship between IC and innovation performance? Q4. How do traditional (Q4a. human capital) and new IC components interact with each other to generate innovation performance?	Publication 3 'to deepen the current understanding of these human components of innovation activity across high-tech and low-tech companies'.	IC components: - Human capital - Entrepreneurial capital - Renewal capital Overall innovation	- SEM based on PLS - Multigroup analysis
Q2. What is the impact of technology level on the relationship between IC and innovation performance? Q4. How do traditional (Q4b. structural and relational capital) and new IC components interact with each other to generate innovation performance?	Publication 4 'to analyse the complementary role of SC and RC, as codification and personalisation outcomes, in organisational renewal and innovation in high-tech and low-tech companies'.	IC components: - Structural capital - Int. relational capital - Ext. relational capital - Renewal capital Overall innovation	- Descriptive analyses - SEM based on PLS - Multigroup analysis

(1) 'Publication and focus' contains quotations from the publications. Each quotation corresponds to the publication referred to in the same cell.

4 Summary of the publications and review of the results

This section presents a summary of the four publications that constitute this dissertation, with a careful discussion of background and objectives on the one hand, and the results and contribution on the other.

4.1 Publication 1: SLR about IC and innovation

4.1.1 Background and objective

Innovation is the mainstay of survival in the current age of revolution (Hamel 2000). Today's business environment is globalised, constantly changing, extremely competitive and dominated by fast technological advances, increasingly short product lifecycles and ever-changing customer preferences (Lee & Tsai 2005; Du Plessis 2007; Tidd & Bessant 2009). Accordingly, finding ways of being innovative is a major issue and huge challenge for companies.

IC, which is the sum of all knowledge own or managed by the company (Youndt et al. 2004), has been consistently linked to innovation. As innovation entails the creation of new knowledge and ideas (Nonaka & Takeuchi 1995; Du Plessis 2007), the knowledge resources governed by the company are conducive to innovation. This relationship has been widely demonstrated in a variety of studies linking IC with product innovation (Wu et al. 2007; Leitner 2011); product, process and managerial innovation (Elsetouhi et al. 2015); incremental and radical innovation (Subramaniam & Youndt 2005; Wang & Chen 2013); the capability to innovate (Sáenz & Aramburu 2011; Aramburu et al. 2015); and innovativeness (Hsu & Sabherwal 2011; Carmona-Lavado et al. 2013), just to mention a few.

The above studies, which have analysed the IC antecedents of innovation, conceal a number of differences including combinations of IC stocks, diverse methodologies and various types of innovation. However, no previous study has provided a comprehensive understanding about the past evolution, the current state-of-the-art and the future of the literature dealing with the IC–innovation relationship. Consequently, this SLR was developed to review and critique the literature about the IC antecedents of innovation and to outline future research lines.

4.1.2 Results and contribution

The extant literature about the IC antecedents of innovation is rich and offers high-quality knowledge based on which new insights could be developed. A review of 40 articles on this subject identified the main insights of previous research and highlighted some deficiencies that could guide future works. Table 7 presents the insights and critique of the analysed set of studies.

Table 7: Main insights and critique – Publication 1

Category	Main insights and critique
Author type	Of the articles analysed, 92.5% were developed by academics, 2.5% were conducted by practitioners and 5% were done by academics and practitioners working jointly. The low degree of participation of practitioners threatens the connection between research and practice in this field.
Location of the sample of firms	EU: 37.5%; UK: 0%; North America: 10%; Central America: 2.5%; South America: 2.5%; Australia and New Zealand: 2.5%; Asia: 40%; Africa: 5%. EU and Asia publish 77.5% of the papers. Articles published in Central and South America and Africa in 2014 and 2015 seem to be a new trend towards researching in new locations.
Industry of the sample of firms	Manufacturing: 52.5%; Services: 15%; Manufacturing and services: 27.5%; Not explained: 5%. Comparisons of how the relationship between IC and innovation works in manufacturing and service companies are non-existent.
Technology level of the sample of firms	High technology: 50%; Low technology: 15%; High- and low-tech: 20%; Not explained: 15%. Although high-tech companies seem to be preferred, only 17.5% of the articles studying high-tech industries make explicit reference to them. Of the articles studying high- and low-tech industries, none compare how the IC–innovation linkage differs across firms with different level of technological sophistication.
Size of the companies	SMEs: 12.5%; No SMEs: 80%; Combination: 7.5%. Research has mainly focused on big companies. Nevertheless, some recent articles (2014 and 2015) studied SMEs.
Research methods	Quantitative: 92.5%; Qualitative: 5%; Mixed: 2.5%. Quantitative methods do not capture practitioners' views as deep as qualitative ones. Thus, this over-representation of quantitative methods does not help to connect research and practice in this domain.
IC components and combinations	Human: 2.5%; Human, structural: 5%; Human, social: 2.5%; Human, social networks: 2.5%; Structural: 5%; Organisational: 2.5%; Social, organisational: 5%; Relational, social: 2.5%; Supplier and customer relationship: 2.5%; **Human, relational, structural: 25%**; Human, structural, social: 5%; **Human, organisational, social: 15%**; Human, organisational, customer: 2.5%; Human, customer, structural: 2.5%; Human, organisation, information: 2.5%; Employee, structural, customer: 2.5%; Human, structural, external social, internal social: 2.5%; Human, social, customer, organisational: 2.5%; Human, technological, customer/relational: 2.5%; Human, technological knowledge, innovation culture: 2.5%; Human, relational, structural, entrepreneur human capital: 2.5%; Internal IC and external IC: 2.5%. The most popular combinations (i.e. Human, relational, structural and human, organisational, social) follow the traditional three-dimensional framework. In addition, all the terms used (apart from 'Entrepreneur HC') can be directly connected to the traditional IC framework. Consequently, the importance of the IC framework developed in the late 1990s is clear in the study of the IC antecedents of innovation. IC components have been defined and understood in various manners across the articles in the field. Hence, diverse ways of operationalising the constructs have emerged. There are currently different definitions and scales for all the IC components, which may threaten the results obtained.

(continued)

Table 7: Main insights and critique – Publication 1

Category	Main insights and critique
Innovation	Innovation as a result: 65%; Degree of radicality: 15%; Innovation as a process: 12.5%; Innovativeness: 7.5%. Some ways of understanding and measuring innovation have not been used very often; thus, there is an opportunity to further examine their meaning and ways of operationalising them. Innovation has been partially represented as the measures utilised do not combine different elements from the four categories identified, i.e. innovation as a result, degree of radicality, innovation as a process and innovativeness.
Research questions and hypotheses	Provides research question: 2.5%; Provides hypotheses: 75%; Provides research question and hypotheses: 15%; Neither research question nor hypothesis: 7.5%. As a great majority of the papers include either research questions, or hypotheses, or both, the field of research could be branded as mature.
Findings and areas of implications	Provides research findings: 100%; Research findings not provided: 0%. Provides research implications: 92.5%; Research implications not provided: 7.5%. Provides practical implications: 80%; Practical implications not provided: 20%. Provides policy implications: 5%; Policy implications not provided: 95%. Although all the articles present their findings, the resulting models about how IC influences innovation contradict each other in some cases. These inconsistencies could be due to differences in the location, industry, technology level and size of the sample of firms analysed. However, an in-depth examination is needed to discern these and/other contingency variables affecting the IC–innovation linkage. As for the implications for research, some articles suggest improving the metrics for measuring IC and innovation, thus supporting the need for determining new ways of operationalising the constructs discussed in prior categories. Implications for practice have a superficial approach as they do not really establish how practitioners could implement the suggested changes. These implications have been developed by academics, without practitioners participating in their design. Most of the articles do not include policy implications.
Subramaniam and Youndt (2005)	Cites Subramaniam and Youndt (2005): 77.5%; Do not cite Subramaniam and Youndt (2005): 22.5%. This seminal article is a reference point for most studies in the field.

The discovered research gaps could be grouped into four groups: (1) a need for a contingency perspective, (2) a disconnect between research, practice and policy, (3) a need for understanding the IC components operating in a firm and (4) partial approaches for measuring innovation.

This review highlighted the need for a contingent approach to the study of the IC antecedents of innovation, as there was no consensus about the way IC components should be strengthened to improve innovation. Researchers in the field proposed multiple models linking IC and innovation, which were in some cases contradictory. It was suggested that differences regarding firms' locations, technology levels, industries and sizes explained this assortment of contradictory models.

Moreover, the review emphasised the urgent need to bridge the gap between researchers on the one hand, and business practitioners and policymakers on the other. Although IC emerged from practitioners (Roos 1998), it was difficult to find evidence of any practitioner developing or helping to develop academic studies about the IC–innovation relationship. This disconnection between academics, practitioners and policymakers lowered the possibility of getting the most out of the relationships between these worlds.

In addition, the traditional IC framework that splits IC into human capital, structural or organisational capital, and relational or social capital (Bontis 1996; Bontis 1998) was the most commonly used. However, the substantial changes that the environment has experienced since the 1990s have most likely affected the way companies operate, thereby raising the question of whether the traditional IC framework remains valid for identifying all knowledge stocks of a company.

Finally, the review brought to the fore the need for new approaches for measuring innovation that provide a complete view of the whole innovation process, since the measures used adopted partial views of the innovation phenomena.

4.2 Publication 2: IC drivers of different innovation types in high- and low-tech firms

4.2.1 Background and objective

The current challenging environment encourages the perpetuation of the so-called KBV (Grant 1996; Spender 1996), and thus, in addition to innovation, knowledge has a prominent role for company survival. Knowledge is a key strategic resource for obtaining sustainable competitive advantages. Along with the relevance of innovation discussed previously, the study of the knowledge-based background of innovation is of utmost importance.

In this regard, evidence in the literature has demonstrated that the IC–innovation linkage is affected by varying levels of technological sophistication on the one hand and different types of innovation on the other. In terms of the technology level, high-tech companies, in contrast to low-tech ones, govern knowledge stocks that are more complex (Schilling 2010), are mainly tacit in form (Nelson & Wright 1992; Rosenbloom 2014) and that ask for frequent renovation (De Carolis 2014). It follows that the relationship between IC and innovation will differ between companies with varying levels of technological sophistication. As for the type of innovation evaluated – that is, the product/service and management innovation – each has its own particularities and thus asks for a different combination of knowledge resources (Damanpour & Aravind 2006; Damanpour & Aravind 2012).

Nevertheless, the existing body of literature that focused on the relationship between IC and innovation has largely omitted the contingencies embedded in how technology level influences the IC–innovation linkage. Furthermore, apart from Elsetouhi et al. (2015) who compared the various knowledge inputs needed for product, process and organisational innovation, and Subramaniam and Youndt (2005) and Wang and Chen (2013), who compared incremental and radical innovation, academic research has neglected how IC changes according to the type of innovation considered. To address those research gaps, this publication analysed the influence of various IC components on both the product/service and managerial innovation in high-tech and low-tech companies. Table 8 (located in Section 4.2.2 Results and contribution) presents the proposed hypotheses and a brief explanation of each one, and Figure 12 shows the structure of the model.

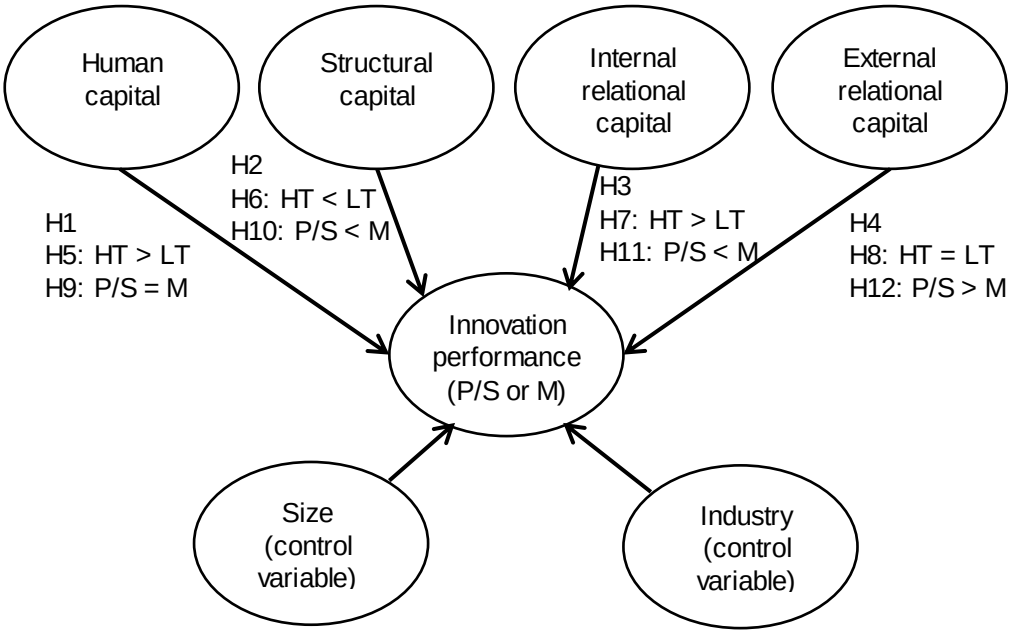

Figure 12: Research model – Publication 2
Note: H1-H12: hypotheses tested; P/S: prod/serv; M: managerial; HT: high-tech; LT: low-tech

4.2.2 Results and contribution

Table 8 presents the hypotheses tested and the results obtained. The outcomes related to product/service innovation are discussed first, followed by an examination of the managerial innovation-related results. As hypotheses H9 to H12 refer to both the product/service and managerial innovation performance, they will be discussed once both types of innovation have been presented.

Table 8: Hypotheses and results – Publication 2

Reasoning	Hypothesis	Result
Innovation is intrinsically a human activity.	H1. Human capital positively affects: (a) Product/service innovation in both (i) high-tech and (ii) low-tech firms; and (b) Managerial innovation in both (i) high-tech and (ii) low-tech firms.	H1ai and H1bi accepted. H1aii and H1bii rejected.
Valuable knowledge repositories (i.e. structural capital) form a solid foundation for innovation.	H2. Structural capital positively affects: (a) Product/service innovation in both (i) high-tech and (ii) low-tech firms; and (b) Managerial innovation in both (i) high-tech and (ii) low-tech firms.	H2aii, H2bi and H2bii accepted. H2ai rejected.
Innovation has a collaborative nature. Knowledge sharing is a key ingredient for knowledge creation.	H3. Internal relational capital positively affects: (a) Product/service innovation in both (i) high-tech and (ii) low-tech firms; and (b) Managerial innovation in both (i) high-tech and (ii) low-tech firms.	Rejected

(continued)

Table 8: Hypotheses and results – Publication 2

Reasoning	Hypothesis	Result
External sources of knowledge are necessary for innovation.	H4. External relational capital positively affects: (a) Product/service innovation in both (i) high-tech and (ii) low-tech firms; and (b) Managerial innovation in both (i) high-tech and (ii) low-tech firms.	H4ai and H4aii accepted. H4bi and H4bii rejected.
High-tech companies manage knowledge that is more complex than that governed by low-tech firms.	H5. The influence of human capital on (a) product/service and (b) managerial innovation performance is significantly larger in high-tech firms than in low-tech firms.	H5a accepted. H5b rejected.
High-tech companies deal with highly tacit knowledge. This type of knowledge is difficult to codify and store.	H6. The influence of structural capital on (a) product/service and (b) managerial innovation performance is significantly lower in high-tech firms than in low-tech firms.	Accepted
The greater degree of tacitness of the knowledge governed by high-tech firms makes internal relations relevant for innovation.	H7. The influence of internal relational capital on (a) product/service and (b) managerial innovation performance is significantly larger in high-tech firms than in low-tech firms.	Rejected
In high-tech firms, the superior knowledge complexity makes it difficult for one firm to have all the required knowledge. Low-tech firms usually lack innovation capabilities.	H8. The influence of external relational capital on (a) product/service and (b) managerial innovation performance is equally relevant in both high- and low-tech firms.	Accepted
Innovation is intrinsically a human activity.	H9. Human capital is equally relevant for both product/service and managerial innovation performance in both (a) high-tech and (b) low-tech firms.	Accepted
Managerial innovation implies changes in the inner workings of the firm that benefit from knowledge codification.	H10. Structural capital is more relevant for managerial innovation performance than for product/service innovation performance in both (a) high-tech and (b) low-tech firms.	Accepted
Managerial innovations have an internal-to-the-firm approach and should thus meet firms' internal needs.	H11. Internal relational capital is more relevant for managerial innovation performance than for product/service innovation performance in both (a) high-tech and (b) low-tech firms.	Rejected
Product/service innovations are developed to satisfy clients' needs.	H12. External relational capital is more relevant for product/service innovation performance than for managerial innovation performance in both (a) high- tech and (b) low-tech firms.	Accepted

Starting with product/service innovation, human capital significantly affected innovation in high-tech firms (H1ai was accepted), while its influence was not significant in low-tech companies (H1aii was rejected). The impact of human capital on product/service innovation was significantly stronger in high-tech firms than in low-tech companies (H5a was accepted). This supported the idea that highly qualified and skilful employees – human capital – played a major role in dealing with the complex knowledge used in the creation of products and services in high-tech firms (Schilling 2010).

By contrast, the influence of structural capital on innovation was not significant in high-tech companies (H2ai was rejected), but it turned out to be significant in low-tech firms (H2aii was accepted). In addition, H6a was also accepted because a significant difference was evident between high-tech and low-tech firms in this regard. In line with Nelson and Wright (1992) and Rosenbloom (2014), the findings showed that explicit knowledge codified and stored in databases and information systems (i.e. structural capital) was a germane enhancer of product/service innovation in firms with low levels of technological sophistication.

Internal relational capital was never significant for innovation (H3ai, H3aii and H7a were rejected), while the opposite holds true for the relationships with external stakeholders. External relational capital significantly enhanced innovation in both high- and low-tech companies (H4ai and H4aii were accepted) and the impact of external relational capital on innovation was equally relevant in high- and low-tech firms (H8a was accepted). Thus, the boundaries in which tacit knowledge is exchanged (i.e. inside the company or with external key partners) affected its usefulness for the creation of products and services. Further, the creation of new products and services benefited from small sizes.

Regarding the amount of variance explained (R^2), this attained 23.52% in the case of high-tech companies and 18.84% in low-tech firms.

Figure 13 and Figure *14* present the resulting models in high- and low-tech companies.

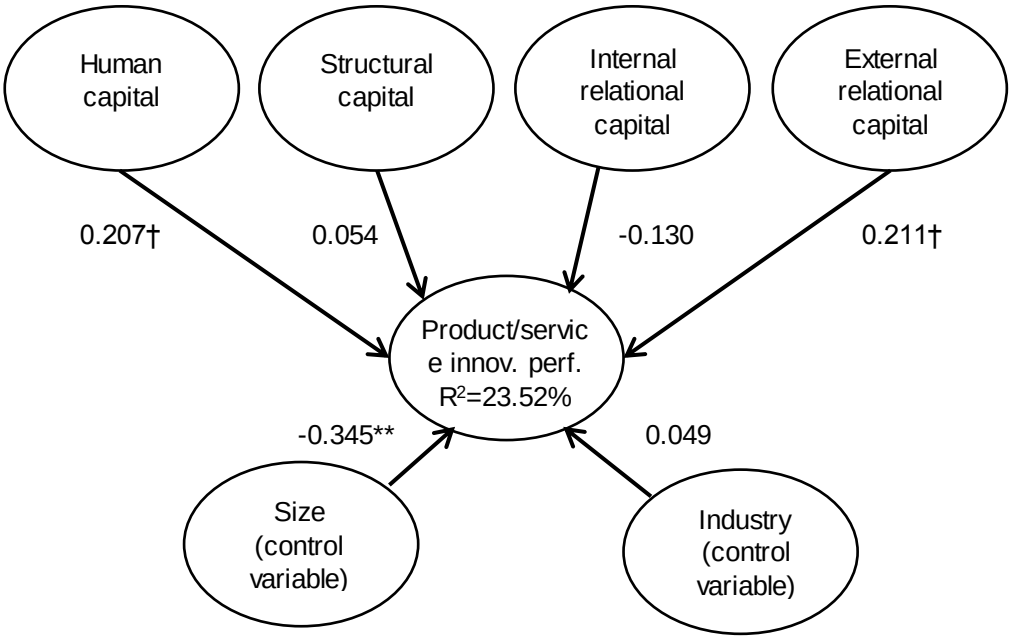

Figure 13: Product/service innovation in high-tech firms – Publication 2
Notes: ***p<.001, **p<.01, *p<.05, †p<.1 (based on t_{499}, one-tailed test).

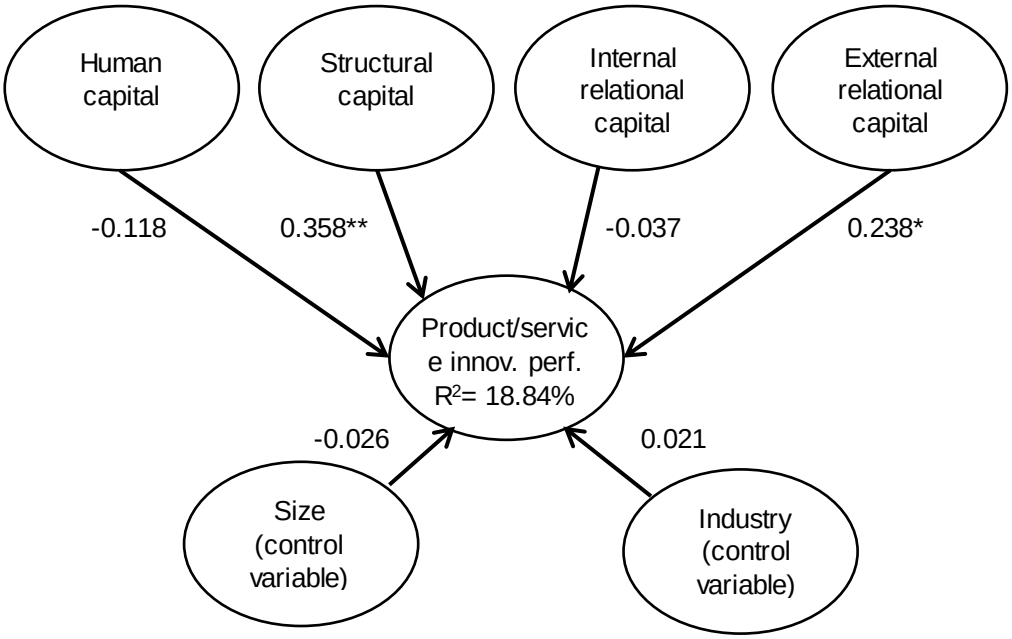

Figure 14: Product/service innovation in low-tech firms – Publication 2
Notes: ***p<.001, **p<.01, *p<.05, †p<.1 (based on t_{499}, one-tailed test).

With respect to managerial innovation, human capital significantly enhanced innovation in high-tech firms (H1bi was accepted); thus, as high-tech companies govern complex knowledge (Schilling 2010), outstanding employees are sorely needed for managerial innovation. Although the human capital-innovation linkage was non-significant in low-tech companies (H1bii was rejected), this difference between high- and low-tech firms was not significant (H5b was rejected).

Structural capital promoted innovation irrespective of the technology level of the firms (H2bi and H2bii were accepted). In accord with the inner characteristics of managerial innovations (Damanpour & Aravind 2012), the codified knowledge stored in databases and information systems (i.e. structural capital) presented a prominent role. Nevertheless, the influence of structural capital on innovation was significantly lower in high-tech than in low-tech companies (H6b was accepted).

Against expectations, both internal and external relational capital seemed to be irrelevant for enhancing innovation regardless of a company's technology level (H3bi, H3bii and H7b were rejected; H4bi and H4bii were rejected, while H8b was accepted).

Concerning the amount of variance explained through the IC components considered, 20.58% of the variance was explained in high-tech firms and 25.95% in low-tech companies.

Figure 15 and Figure *16* show the models linking IC and managerial innovation performance in high- and low-tech companies.

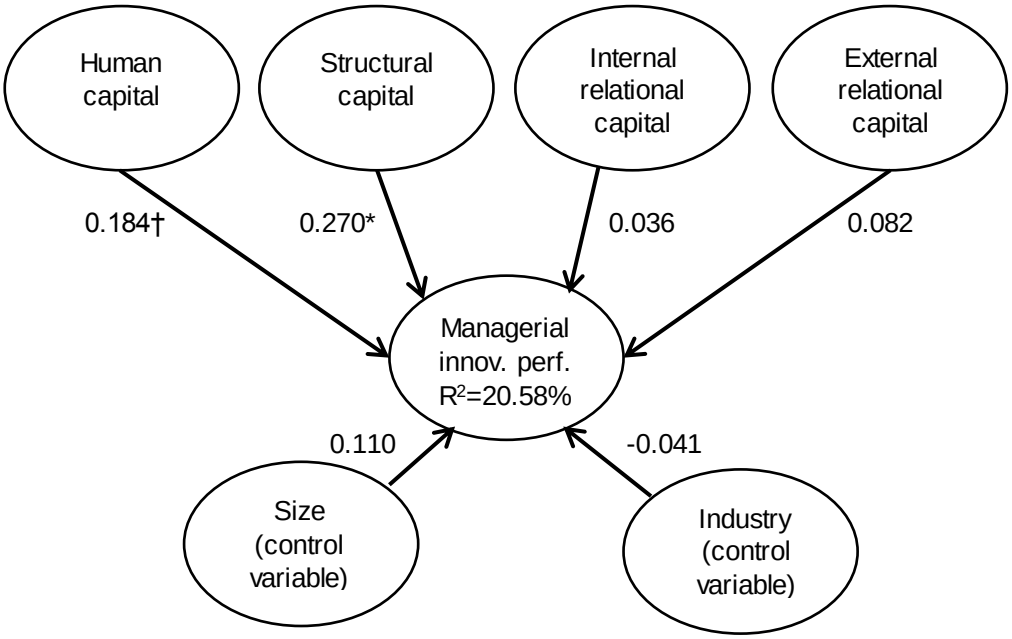

Figure 15: Managerial innovation in high-tech firms – Publication 2
Notes: ***p<.001, **p<.01, *p<.05, †p<.1 (based on t_{499}, one-tailed test).

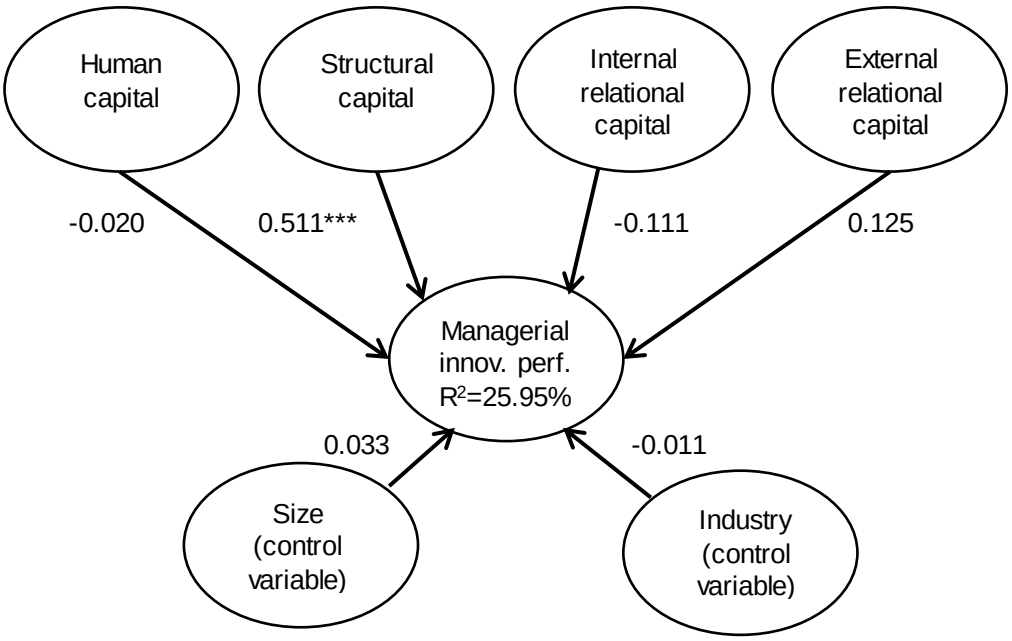

Figure 16: Managerial innovation in low-tech firms – Publication 2
Notes: ***p<.001, **p<.01, *p<.05, †p<.1 (based on t_{499}, one-tailed test).

Regarding the differences ingrained in the type of innovation considered (H9 to H12), as innovation is intrinsically a human activity, human capital was equally relevant for both product/service and managerial innovation performance (H9 was accepted). As expected, the role of structural capital was more relevant for promoting managerial innovation than for enhancing product/service innovation; thus, H10 was accepted. Since internal relational capital turned out to be irrelevant for enhancing product/service and managerial

innovation performance, H11 was rejected. Moreover, while external relational capital did not significantly influence managerial innovation performance, the opposite happened in the case of product/service innovation; hence, hypothesis H12 was accepted.

As previous models show, some IC components seemed to be irrelevant for enhancing either product/service or managerial innovation performance. To conclude whether those components were definitely not relevant or whether their influence was mediated by other components, post-hoc analyses were carried out. In the case of product/service innovation performance, structural and internal relational capital in high-tech companies, and human and internal relational capital in low-tech firms were certainly irrelevant. Consequently, Figure 13 and Figure *14* show the final models.

Regarding managerial innovation performance, some mediating relationships among IC components were discovered. In high-tech companies, as in the model prior to the post-hoc analyses, human and structural capital directly enhanced the creation of new management practices and organisational methods. However, internal relational capital, which appeared to be irrelevant for innovation, showed an indirect impact on managerial innovation. Given that the creation of new management practices has an internal-to-the-firm approach (Damanpour & Aravind 2012), relationships among employees – i.e. internal relational capital – influenced innovation by boosting both human and structural capital. Further, external relational capital also showed an indirect impact on the development of new management practices and organisational methods. Knowledge coming from outside the boundaries of the firm enhanced individual knowledge, skills and abilities, i.e. human capital.

In the case of low-tech companies, structural capital exerted a direct impact on the creation of new management practices and organisational methods and mediated the influence of human and internal and external relational capital on innovation. As low-tech companies tend to work with explicit knowledge (Nelson & Wright 1992; Rosenbloom 2014), the prominent role of structural capital when enhancing managerial innovation became even more important than in high-tech firms. Moreover, the internal-to-the-firm approach characteristic of the creation of new management practices (Damanpour & Aravind 2012) contrasted with the role of internal relational capital as a mere enhancer of structural capital.

As for the amount of variance explained, 19.77% and 24.97% of the variance was explained in high-tech firms and in low-tech companies respectively.

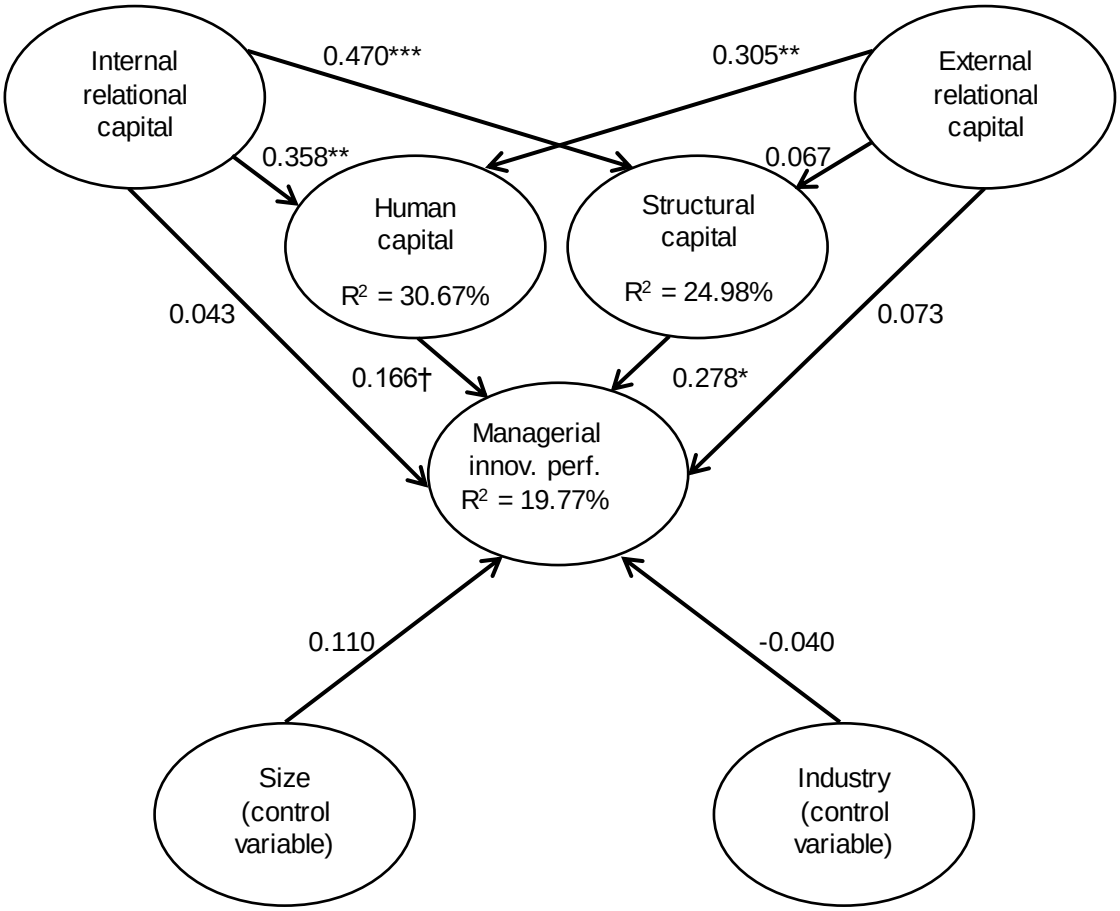

Figure 17: Post-hoc model – Managerial innovation in high-tech firms – Publication 2
Notes: ***p<.001, **p<.01, *p<.05, †p<.1 (based on t_{499}, one-tailed test).

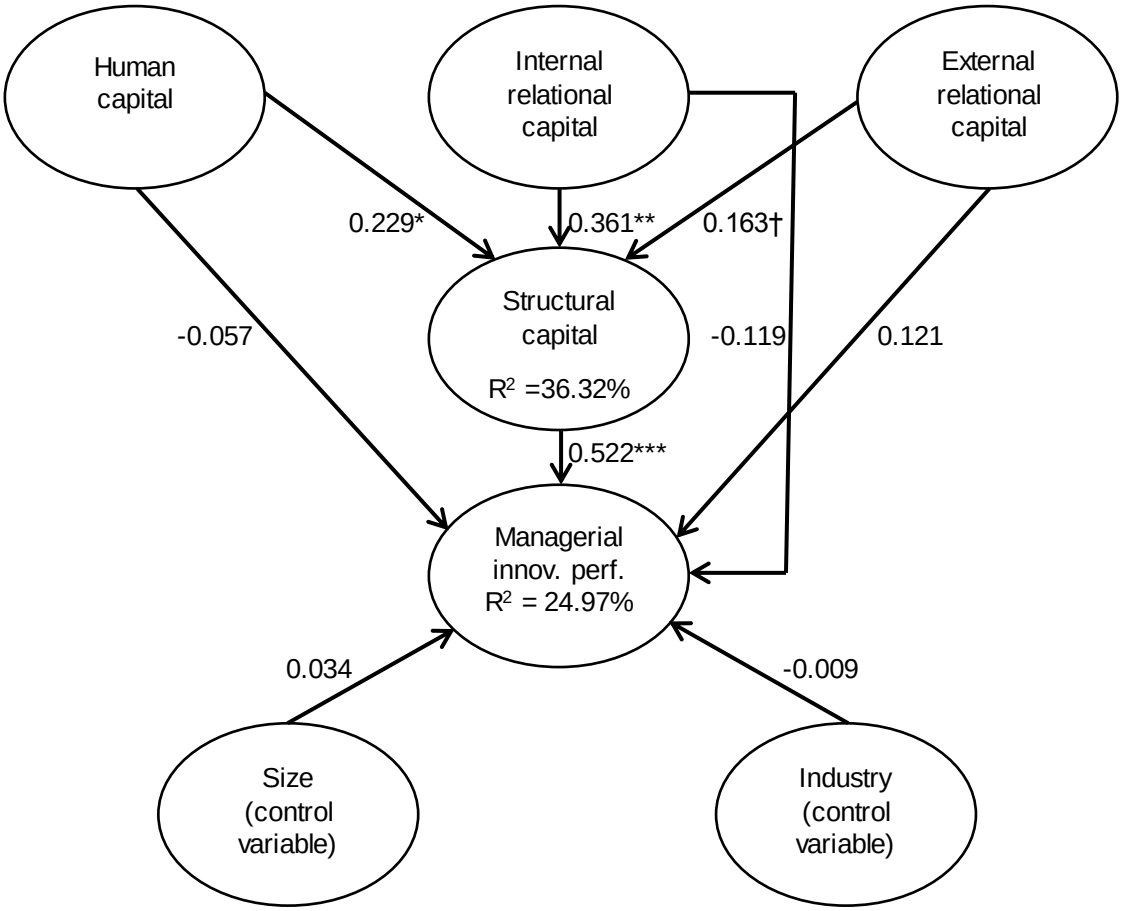

Figure 18: Post-hoc model – Managerial innovation in low-tech firms – Publication 2
Notes: ***p<.001, **p<.01, *p<.05, †p<.1 (based on t_{499}, one-tailed test).

This publication contributed to the literature by demonstrating that the technology level and type of innovation were contingencies affecting the IC–innovation relationship, thus adding to the debate on the contingency perspective of IC (Subramaniam & Youndt 2005; Reed et al. 2006). On the one hand, the technological sophistication of companies altered the IC components influencing innovation and the way in which that relationship worked. On the other hand, it gave prominence to the knowledge-based differences ingrained in various innovation types.

4.3 Publication 3: Exploring the role of human-related characteristics in innovation in high- and low-tech firms

4.3.1 Background and objective

The current business environment asks companies to discern creative and innovative ways of competing in the marketplace (Hamel 2000; Lee & Tsai 2005; Du Plessis 2007; Tidd & Bessant 2009). Innovation or the creation of new knowledge (Nonaka & Takeuchi 1995; Du Plessis 2007) is thus a requirement. In an effort to discover ways of enhancing innovation, researchers in the IC field have widely analysed how IC – the sum of

knowledge resources owned or governed by a company (Youndt et al. 2004) – influences innovation (Subramaniam & Youndt 2005; Cabello-Medina et al. 2011; Leitner 2011).

Though human capital is the core resource of any company (Wright et al. 1994; Roos & Roos 1997; Sveiby 1997), studies linking IC and innovation adopt a rather superficial view of it. Creating new knowledge and transforming it into products, services, processes and any other creation demands knowledge workers with specific characteristics, such as the ability to identify and pursue opportunities, the ability to assume risks, make difficult decisions and show initiative (i.e. entrepreneurial capital), and the ability to consistently learn and update the knowledge-base (i.e. renewal capital). Nevertheless, research works do not often delve into specific human resource capabilities crucial for enhancing innovation (i.e. entrepreneurial and renewal capital) but tend to follow a perfunctory approach to the study of individuals.

To expand the understanding of the human side of the innovation activity, this study considered entrepreneurial and renewal capabilities, along with traditional human capital, as meaningful human-related characteristics influencing innovation performance. Traditional human capital represents individuals' qualification and motivation. Given that individuals can adopt entrepreneurial behaviours and learn and update their knowledge-bases (Stevenson & Jarillo 1990; Hsu & Fang 2009), human capital is expected to influence both entrepreneurial and renewal capital. Further, the technology level of the company was given careful consideration to continue the discussion about the contingency perspective of IC. Figure 19 depicts the structure of the research model.

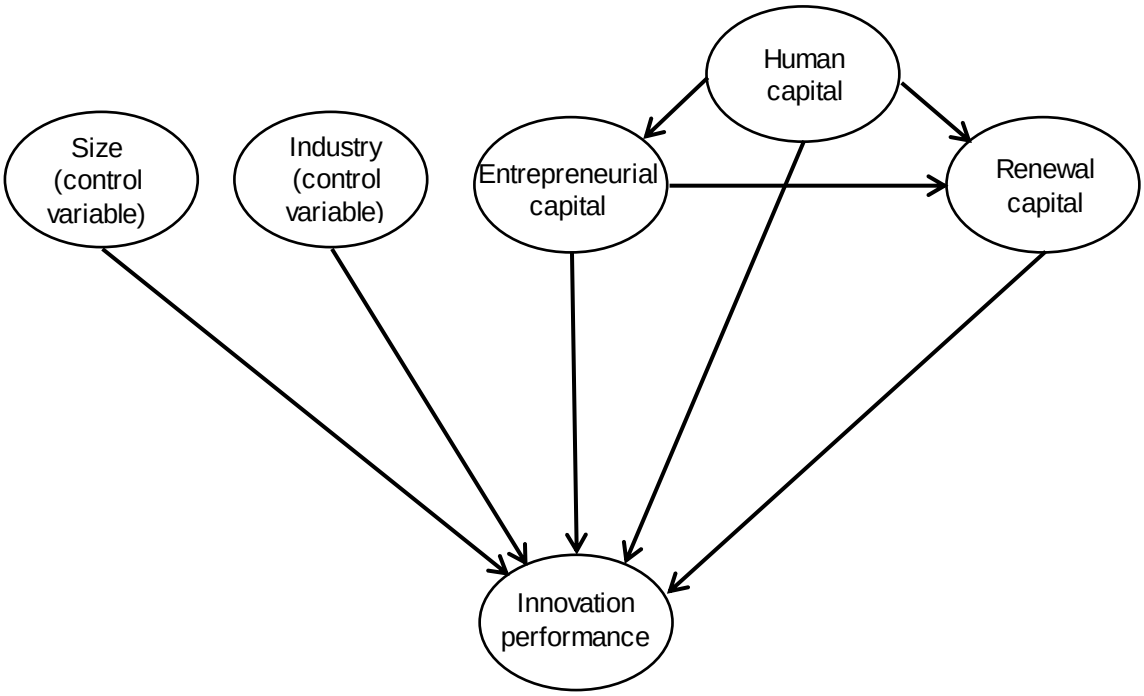

Figure 19: Research model – Publication 3

4.3.2 Results and contribution

Table 9 shows the hypotheses that were verified and the results obtained. As can be seen, all the hypotheses suggested, apart from H5 and H6, were fully accepted. In the case of H5, entrepreneurial capital did not directly influence innovation in low-tech firms; thus,

renewal capital was a full mediator in the relationship between entrepreneurial capital and innovation performance (H5 was accepted in high-tech firms and rejected in low-tech companies). As for H6, contrary to expectation, human capital had no direct impact on innovation; hence, the relationship between human capital and innovation was fully mediated by entrepreneurial and renewal capital in high-tech companies, and it was fully mediated by renewal capital in low-tech firms (H6 was rejected). Table 9 presents the hypotheses tested and the paragraphs that follow explain the models drawn for high- and low-tech companies.

Table 9: Hypotheses and results – Publication 3

Reasoning	**Hypothesis**	**Result**
Individuals are those that perform entrepreneurial activities and show entrepreneurial behaviours.	H1. Employees' level of qualification and motivation (human capital) will determine their entrepreneurial attitude (entrepreneurial capital).	Accepted
Being proactive, in search for new opportunities and willing to assume risks (entrepreneurial capital) stresses the need of learning.	H2. Employees' level of entrepreneurial attitude (entrepreneurial capital) will determine their capability to learn and renovate the company's knowledge base (renewal capital).	Accepted
Human capital could promote other relevant capabilities that contribute to learning beyond entrepreneurial capital.	H3. Employees' level of entrepreneurial orientation (entrepreneurial capital) partially mediates the relationship between their level of qualification and motivation (human capital) and their ability to learn and to renovate the company's knowledge base (renewal capital).	Accepted
The creation of new knowledge or new combinations of existing knowledge (i.e. innovation) will depend on the current ability to renovate existing knowledge.	H4. Employees' ability to learn and to renovate the company's knowledge base (renewal capital) will enhance innovation performance.	Accepted
Entrepreneurial capital could promote other relevant capabilities that contribute to innovation beyond renewal capital.	H5. Employees' ability to learn and to renovate the company's knowledge base (renewal capital) partially mediates the relationship between employees' level of entrepreneurial attitude (entrepreneurial capital) and innovation performance.	Accepted for high-tech. Rejected for low-tech.

(continued)

Table 9: Hypotheses and results – Publication 3

Reasoning	Hypothesis	Result
Innovation is intrinsically a human activity; hence, human capital is essential for innovation. Given prior reasons supporting the above hypotheses, it could be suggested that both entrepreneurial and renewal capital partially mediate the linkage between human capital and innovation performance.	H6. Employees' level of entrepreneurial attitude (entrepreneurial capital) and their ability to learn and to renovate the company's knowledge base (renewal capital) partially mediate the relationship between employees' level of qualification and motivation (human capital) and innovation performance.	Rejected
Knowledge managed in high-tech and low-tech firms differ considerably.	H7. The technology level of the firm will affect the strength of the previously described relationships.	Accepted (the linkages between size, entrepreneurial and renewal capital, and innovation significantly differ)

As innovation performance in high-tech firms was boosted directly by entrepreneurial and renewal capital, excluding them from the study would have weakened the results. In particular, the link between entrepreneurial capital and innovation was significantly stronger in high-tech companies, which seemed to be explained by the more disruptive kind of innovation that characterised the companies in this group. Human capital did not directly affect innovation, but the impact was indirect through entrepreneurial and renewal capital. Hence, the ability to identify opportunities, take risks and make difficult decisions (i.e. entrepreneurial capital), and the capacity to learn and renovate the knowledge base (i.e. renewal capital) were greatly improved by human capital. Indeed, the linkage between human and renewal capital was significantly stronger (very close to being significant according to the differences in paths) in high-tech firms due to the increasing complexity and high renovation frequency of the knowledge managed in these companies (Schilling 2010; De Carolis 2014). Moreover, entrepreneurial capital contributed to the ability to learn and update the knowledge base – i.e. to renewal capital – and size negatively impacted on innovation; thus, the creation of novelties benefited from small sizes. In addition, the human-related resources considered explained 32.41% of the variance of innovation performance.

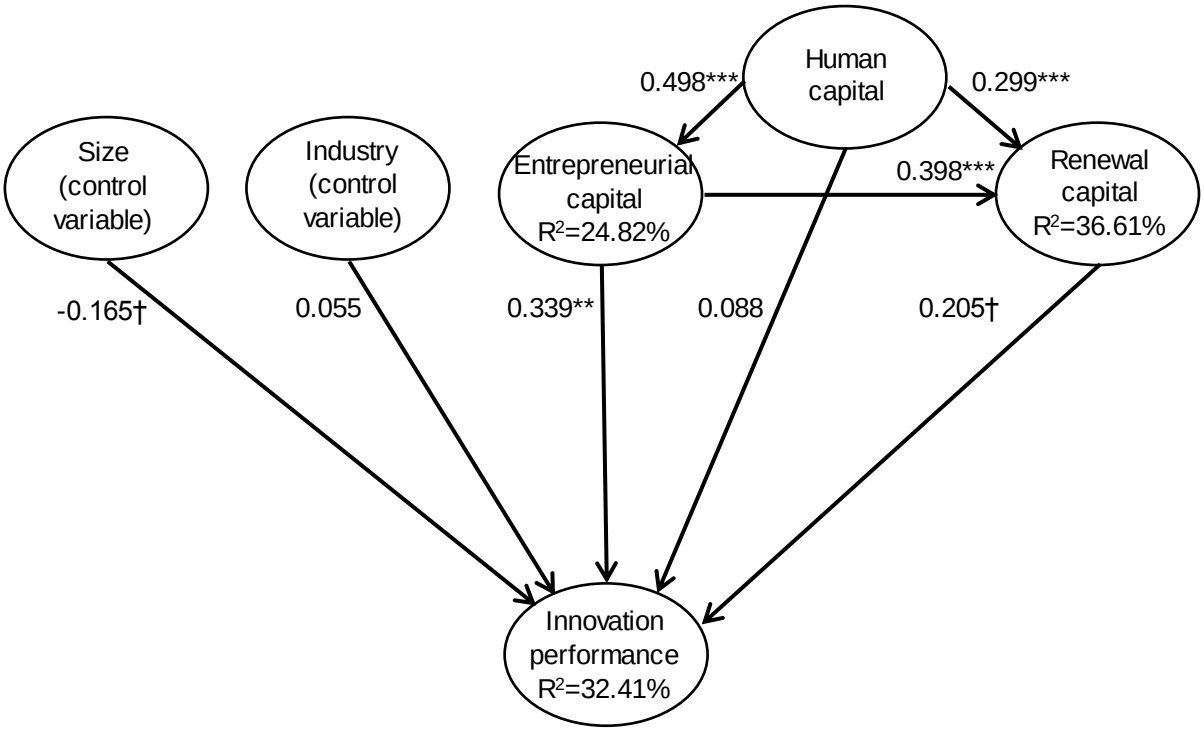

Figure 20: Model for high-tech firms – Publication 3
Notes: ***p<.001, **p<.01, *p<.05, †p<.1 (based on t_{499}, one-tailed test).

Regarding low-tech companies, renewal capital was the only human-related resource that had a direct impact on innovation performance. This relationship was significantly stronger in low-tech companies since these companies tend to pursue incremental rather than radical changes. Individual qualification, skill base and motivation (i.e. human capital) configured the basis upon which new knowledge could be learned and subsequently converted into new products, processes and other novelties; thus, human capital contributed to innovation by means of renewal capital. In the case of entrepreneurial capital, learning and renovating the knowledge base helped to transform identified opportunities into real innovations; hence, entrepreneurial capital enhanced innovation by means of renewal capital. Further, these knowledge-based antecedents of innovation were able to explain 42.13% of its variance.

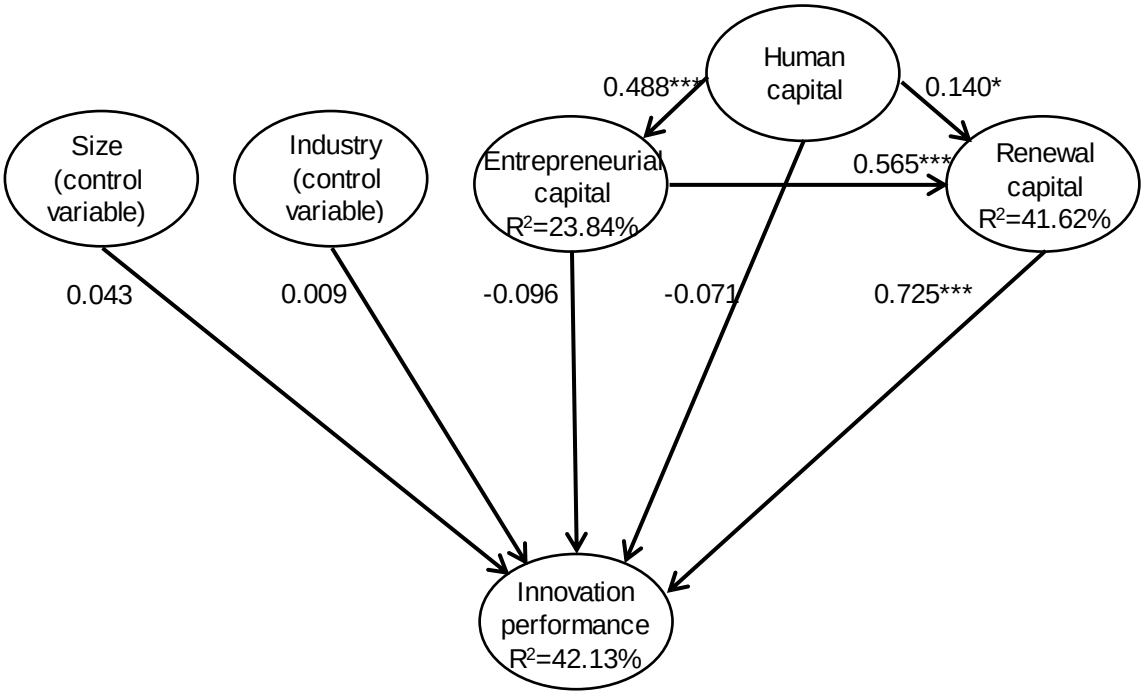

Figure 21: Model for low-tech firms – Publication 3
Notes: ***p<.001, **p<.01, *p<.05, †p<.1 (based on t_{499}, one-tailed test).

This publication contributed to the literature about the IC–innovation relationship by offering a deeper understanding of the human-related antecedents of innovation. The combination of a traditional IC component (i.e. human capital) and two new people-related IC components (i.e. entrepreneurial and renewal capital) was deemed beneficial for enhancing the understanding of the knowledge-related antecedents of innovation. Furthermore, by including the level of technological sophistication, the study provided a more nuanced comprehension of the contingencies affecting the way IC resources influenced innovation.

4.4 Publication 4: KM strategies, IC and innovation: a comparison between high- and low-tech firms

4.4.1 Background and objective

As previously discussed, companies' urgent need to excel in innovation if they are to survive and grow (Hamel 2000; Lee & Tsai 2005; Du Plessis 2007) makes the analysis of its antecedents highly worthwhile. While the IC–innovation relationship has been widely analysed, the influence of the level of technological sophistication has been largely omitted. Studies in this field have also failed to include IC components other than traditional ones. Renewal capital is the ability to learn and update the knowledge base (Kianto et al. 2010). Even though it stems from the founding literature on IC, it has rarely been introduced in the IC framework.

In addition to the traditional IC framework, IC presents a dynamic perspective that refers to 'the organisational capabilities to leverage, develop and change intangible assets for value creation' (Kianto 2007, p.344). As KM includes 'all the activities that utilize

knowledge to accomplish the organizational objectives' (Greiner et al. 2007, p.4), this dynamic approach to IC overlaps with KM. However, IC and KM are, at present, two independent streams of research that few scholars have attempted to merge (e.g. Kianto et al. 2014; Handzic & Durmic 2015).

The strategies for managing knowledge (i.e. KM strategies) are likely to affect the ability to learn and update the knowledge base (i.e. renewal capital). Among the various KM strategies, codification and personalisation (Hansen et al. 1999) are of great relevance. Codification argues for storing knowledge using a people-to-documents approach and disseminating it through electronic document systems (Hansen et al. 1999), whereas personalisation claims for a person-to-person approach; therefore, the webs of relationships among individuals are the main way of transferring tacit knowledge (Hansen et al. 1999). Consequently, those companies enhancing a codification-based KM strategy tend to have well-developed structural capital, whereas firms promoting a personalisation-based KM strategy are more likely to support the development of relational capital.

Alongside the pressing need of companies to innovate, the almost unexplored connection between IC and KM, the lack of studies analysing renewal capital along traditional IC components and the poor understanding of the influence of technology level on the IC–innovation relationship guided this study towards analysing the complementary role of structural and relational capital – as the manifestation of codification and personalisation outcomes – in renewal capital and innovation in high-tech and low-tech companies. Figure 22 presents the research model tested in this publication.

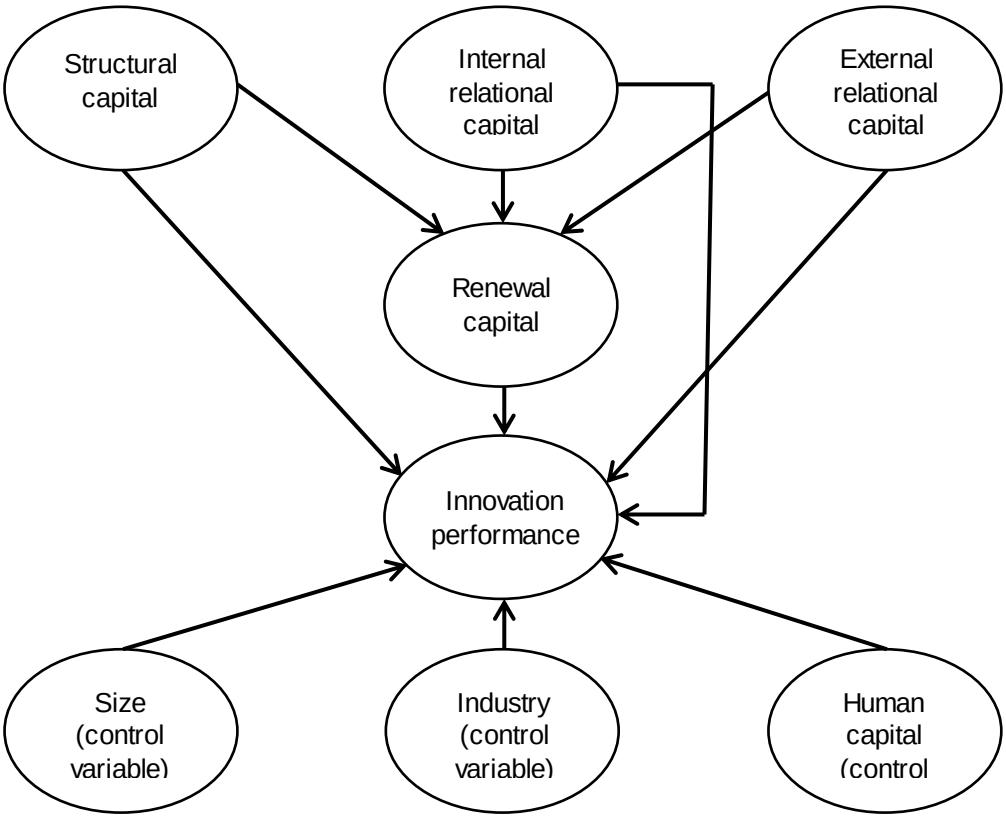

Figure 22: Research model – Publication 4

4.4.2 Results and contribution

Table 10 presents the hypotheses tested and the results obtained. The paragraphs following Table 10 discuss the hypotheses and explain the models built for high-tech and low-tech companies.

Table 10: Hypotheses and results – Publication 4

Reasoning	Hypothesis	Result
Codified knowledge is necessary for learning, and consequently, for knowledge renewal.	H1. Structural capital promotes renewal capital in both (i) high-tech and (ii) low-tech firms.	Accepted
Learning and renovating the knowledge base depend also on tacit knowledge, which is only accessible by means of person-to-person interactions.	H2. (a) Internal and (b) external relational capital foster renewal capital in both (i) high-tech and (ii) low-tech firms.	Accepted
Learning is required for knowledge renewal. Knowledge, skills and capacities acquired in the learning process enhance innovation.	H3. Renewal capital fosters innovation performance in both (i) high-tech and (ii) low-tech firms.	Accepted
Up-to-date knowledge repositories and databases configure a solid foundation for innovation.	H4. Structural capital promotes innovation performance in both (i) high-tech and (ii) low-tech firms.	H4i rejected. H4ii accepted.
Innovation is a collaborative activity. Tacit knowledge shared among employees and with external parties is necessary for knowledge creation.	H5. (a) Internal and (b) external relational capital foster innovation performance in both (i) high-tech and (ii) low-tech firms.	H5a and H5bi rejected. H5bii accepted.
Previous studies proved that learning, which is required for knowledge renovation, mediates the linkage between structural, internal and external relational capital, and innovation. This mediating role of renewal capital is also suggested in prior hypotheses (H1 to H5).	H6. The influence of structural and both (a) internal and (b) external relational capital on innovation performance is partially mediated by renewal capital in both (i) high-tech and (ii) low-tech firms.	H6i for structural capital, H6ai and H6bi were rejected. H6ii for structural capital and H6bii were accepted. H6aii rejected.
High- and low-tech firms govern knowledge with varying characteristics.	H7. The technology level of the firm affects the strength of the previously described relationships.	Partly accepted (structural capital-innovation and renewal capital-innovation relationships).

Regardless of the technology level of the firm, renewal capital was enhanced by structural and both internal and external relational capital (H1 and H2 were accepted). Hence, explicit and tacit knowledge seemed to be required for learning and, by doing so, updating the knowledge base. As expected, renewal capital had a significant impact on innovation performance in both high- and low-tech companies (H3 was accepted). However, while in low-tech companies, innovation was supported by various IC components, renewal capital was the only innovation enhancer in high-tech firms. Thus, H4i, H5a and H5bi were rejected and H4ii and H5bii were accepted.

As high-tech companies need to renovate their knowledge base more frequently (De Carolis 2014), renewal capital presented a prominent role in the creation of novelties. Codified knowledge stored in databases and information systems (i.e. structural capital) and tacit knowledge exchanged with external partners (i.e. external relational capital) contributed to innovation only by improving the ability to learn and to renovate the knowledge base (i.e. renewal capital) (H6i for structural capital and H6bi were rejected as full rather than partial mediation applied). By contrast, internal relational capital seemed to be valuable for learning (i.e. renewal capital), but not significant for innovating in companies that manage highly complex knowledge (Schilling 2010) (H6ai was rejected). Furthermore, the behaviour of control variables could also be understood from the knowledge-related differences between high- and low-tech firms. As high-tech companies deal with increasingly complex knowledge (Schilling 2010), and it requires frequent renovation (De Carolis 2014), human resources should be and were especially knowledgeable, and small size firms that are very agile were highly desirable. Besides, 39.32% of the variance of renewal capital and 28.64% of the variance of innovation performance were explained.

As for low-tech firms, innovation performance was directly affected by the four IC components considered. Structural capital and both internal and external relational capital influenced innovation both directly and through renewal capital (H6ii for structural capital and H6bii were accepted). However, in the case of tacit knowledge exchanged among employees – i.e. internal relational capital – the impact on innovation was negative (H6aii was rejected). Interactions among individuals in the same company that do not have a straightforward learning orientation tended to be counterproductive for innovation.

Moreover, since low-tech firms have a clear orientation towards managing explicit knowledge (Nelson & Wright 1992; Rosenbloom 2014), structural capital was significantly more relevant for innovation in these companies than in high-tech ones. Even though low-tech firms do not renew their knowledge base as frequently as do high-tech companies (De Carolis 2014), the linkage between renewal capital and innovation performance was significantly stronger in low-tech companies than in high-tech ones. Therefore, the low-tech firms that excel in innovation were likely to enhance the ability to learn and to renovate their knowledge bases (i.e. renewal capital).

The post-hoc analyses performed to understand the apparently negative relationship between human capital (control variable) and innovation showed that mediation relationships were taking place. Since low-tech firms manage simple knowledge (Schilling 2010), human resources did not have such a prominent role in the enhancement of innovation. Instead, human capital affected innovation through fostering the remaining IC components. The amount of variance explained was higher than in the previous model, being 43.30% for renewal capital and 48.60% for innovation performance.

Finally, the multigroup test revealed that the structural capital-innovation relationship and the renewal capital-innovation linkage differ significantly between high-tech and low-tech companies. Thus, H7 was partly accepted. Figure 23 and Figure *24* show the models presented in this publication.

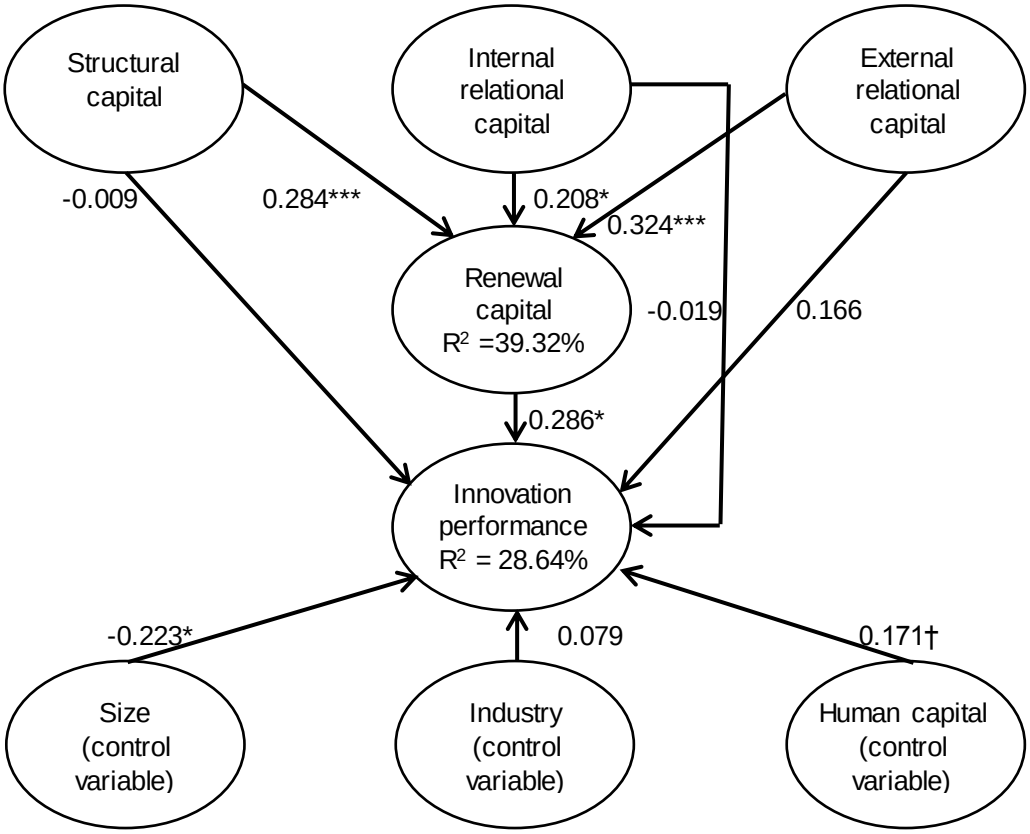

Figure 23: Model for high-tech firms – Publication 4
Notes: ***p<.001, **p<.01, *p<.05, †p<.1 (based on t_{499}, one-tailed test).

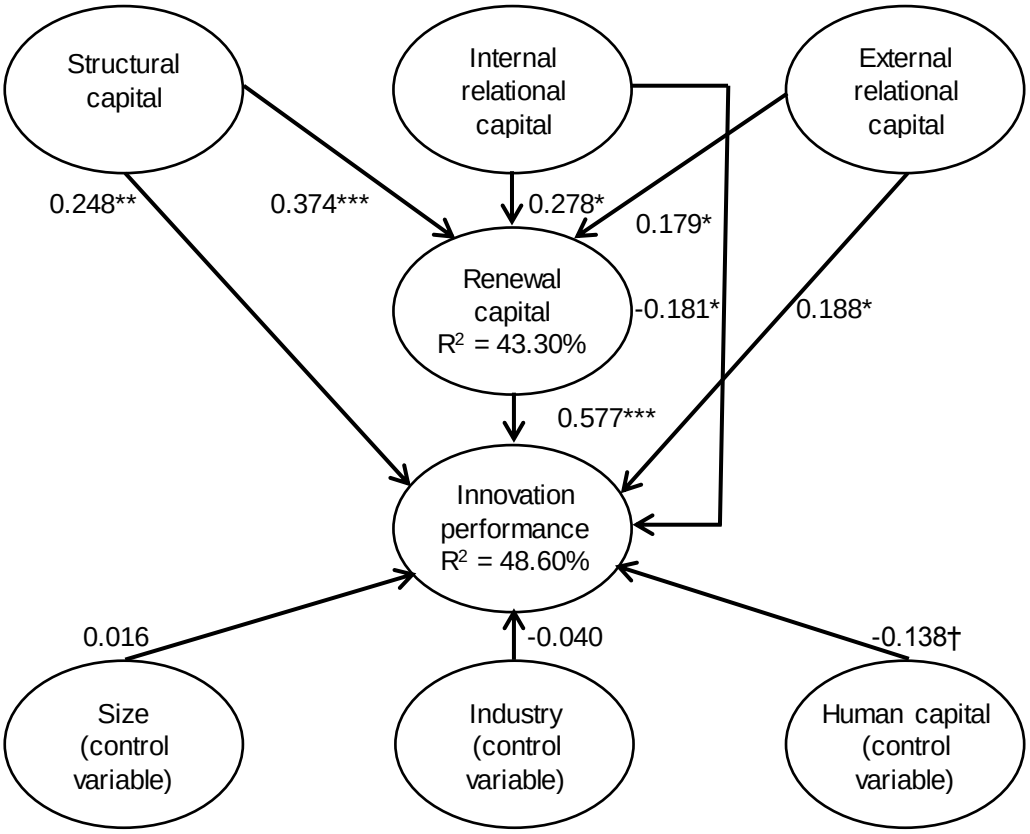

Figure 24: Model for low-tech firms – Publication 4
Notes: ***p<.001, **p<.01, *p<.05, †p<.1 (based on t_{499}, one-tailed test).

This publication contributed to the literature in three ways. First, it examined renewal capital in conjunction with traditional IC components and it showed the relevant role of renewal capital for supporting innovation performance. Thus, renewal capital seemed to deserve a place among the other IC components commonly analysed. Second, this publication added to the scarcely addressed debate about the connection between KM and IC components by offering a theoretical reflection on it. Finally, the publication demonstrated how the differences ingrained in the technology level of companies affected the IC–innovation relationship and thus offered a more nuanced approach to this well-known relationship.

5 Discussion and conclusions

This study examined the specificities of the IC–innovation relationship. In particular, the dissertation analysed the influence of both traditional and new IC components on different types of innovation performance in companies with different levels of technological sophistication. The research started with a critical review of the IC–innovation research field that offered valuable insights and uncovered several research gaps. After that, varying models linking IC components and innovation performance were developed and tested in three empirical publications. These theoretically and empirically grounded research findings contributed to the literature on creating, leveraging and managing IC.

5.1 Answering the research questions

This dissertation was designed to answer the following research question: How do traditional and new IC components affect innovation in companies with different levels of technological sophistication? This challenge was further split into four sub-questions, which are answered below.

The first sub-questions related to the lack of a critical review of the IC–innovation research field. Publication 1 answered the following questions: How is research for inquiring into the IC–innovation relationship developing? What is the focus of the IC–innovation relationship literature? and What is the future for the IC–innovation relationship literature? This group of three questions provided the main insights and critique about the IC–innovation research field and the potential research lines that might be addressed in the future.

By analysing the 16 categories included in the analytical framework (see Figure 9 in Section 3.2.2 Analytical framework), the publication answered the first two questions about the insights and critique of the analysed literature (see Table 7 in Section 4.1.2 Results and contribution). Taking into consideration the first two questions, the review identified four areas that might deserve further scrutiny.

First, among the many empirical studies disentangling the IC antecedents of innovation, there was no agreement on how knowledge-related resources influence innovation. The reason behind this disagreement was likely to be the lack of a contingency perspective that explores how a firm's location, technology level, industry and size affect the IC–innovation relationship. While these variables are prone to affect IC and innovation (Nelson & Wright 1992; Nooteboom 1994; Hipp & Grupp 2005; Cohen & Kaimenakis 2007; Hofstede et al. 2010; Kianto et al. 2010; Schilling 2010; De Carolis 2014; Rosenbloom 2014), the revised literature did not take them into account.

Second, the review found that the traditional IC framework prevails in the IC–innovation research field. While understanding the value and usefulness of the traditional framework, the environment in which companies operate has suffered major changes (OECD 2015a; OECD 2015b) that have likely altered the inner working of companies. Thus, the question remains as to whether companies' knowledge-related assets are fully represented by the traditional IC framework.

Another recurrent theme was the way of measuring innovation. The articles revised in the SLR adopted partial approaches to innovation because they mainly focused on the results

obtained and, among them, on product innovation. Other aspects related to the innovation activity, such as process innovation or the ability to innovate, as well as the combination of various measures that might provide a deeper understanding of the phenomena, remained underrepresented.

The fourth area refers to the disconnect between academics, practitioners and policymakers when it comes to disentangling the IC antecedents of innovation. As for the researcher–practitioner disconnection, practitioners were involved in very few studies among those analysed; qualitative research, which is close to the participant, was almost never applied; and the practical implications offered by the articles analysed were largely superficial and failed to explain how managers could put in practice the models tested. In terms of the disconnect between academic and policymaking worlds, it was hard to find any study that included a recommendation for policy.

Publications 2, 3 and 4 addressed the next sub-question: What is the impact of technology level on the relationship between IC and innovation performance? As expected, the models drawn in these three publications differed between high- and low-tech companies, thereby emphasising the differences ingrained in the level of technological sophistication when it comes to analysing the IC antecedents of innovation. An examination of the specificities of these differences showed that the way in which the technological sophistication of companies affected the IC–innovation relationship was not fully predictable. The level of complexity, the degree of tacitness and the pace of renovation that differ between high- and low-tech companies (Nelson & Wright 1992; Schilling 2010; De Carolis 2014; Rosenbloom 2014) were expected to make human, internal relational, entrepreneurial and renewal capital far more important for innovation in high-tech firms. Structural capital was likely to be more relevant for innovation in low-tech companies. As for external relational capital, it was regarded either equally relevant in both high- and low-tech companies or more important in high-tech firms when it comes to enhancing innovation.

The reason for this apparently unpredictable behaviour is threefold. First, IC components interacted among them when influencing innovation; thus, the predicted impact of the level of technological sophistication when taking each IC component in isolation might be altered when analysing the complete model. For instance, in publication 4, it was expected that external relationships enhanced innovation in high-tech companies as they managed tacit knowledge (Nelson & Wright 1992; Rosenbloom 2014) that could best be communicated via face-to-face interactions. However, the strong connection between renewal capital and innovation seemed to overshadow the impact of external relations so that external relational capital does not exert a direct influence on innovation.

Second, as the varying degree of complexity, tacitness and renovation pace might affect several IC components, each component could be coloured by one or more of these characteristics. Subsequently, the behaviour of each IC component might change according to the specific characteristic influencing it. An example of this could be found in publication 4, which proposed that internal relations among employees were likely to influence innovation performance in high-tech firms due to the high degree of tacitness of the knowledge managed by these companies (Nelson & Wright 1992; Rosenbloom 2014). The results showcased that tacit knowledge created and exchanged in relationships

among employees did not exert a significant direct impact on innovation as the knowledge governed by high-tech corporations is increasingly complex (Schilling 2010). Although personal interaction is likely to be helpful in dealing with complex knowledge, this greater degree of complexity requires widening the scope of personal interactions to include agents external to the firm. Hence, tacitness and complexity seem to go in opposite directions in terms of the need for internal (not external) relational capital. Both characteristics (i.e. the degree of tacitness and the increasing complexity) could affect the behaviour of internal relational capital in high-tech companies, but the final behaviour depends on which one prevailed.

The abovementioned idea leads to the next question: How can we know which knowledge-related characteristic prevails in different situations? This question has no easy answer. The results obtained in the three empirical publications supported the idea that there is a sort of order of prevalence, but they did not offer enough evidence to discern what this order is. To examine this issue more closely, it would be necessary to reflect upon the knowledge-related characteristics that differ between high-tech and low-tech companies (this will be discussed in the next paragraph) and the level of analysis of the IC components. In terms of the level of analysis, this dissertation studied IC at the company level; nevertheless, the knowledge managed in different functional or knowledge areas could differ. For example, employees in the R&D department will deal with radically different knowledge challenges to office workers who carry out routine work. The differences ingrained in the varying functional or knowledge areas might also affect the relevance of each knowledge-related characteristic. Continuing the previous example, it could be likely that for workers in the R&D department, the degree of complexity of the knowledge governed is more important than that for office employees. Changing what knowledge is managed implies variations in which knowledge-related characteristics prevail. Consequently, an investigation into the specific IC components of functional or knowledge areas could be required to understand which knowledge-related characteristic prevails.

The last reason supporting the apparently unpredictable effect of technological sophistication results from the fact that the study conducted did not define the level of complexity, the degree of tacitness or the renovation pace as constructs with associated indicators. There is a need to explore these three characteristics further to understand how each one could affect the IC–innovation relationship in different situations. The findings could help to establish an order of prevalence among knowledge-related characteristics. Other contingency variables different from technology level might also be influencing the IC–innovation relationship and even overshadowing the impact of technological sophistication. This could be the case of the combined impact of technology level and innovation type discussed in publication 2.

Publication 2 answered the third sub-question: What is the influence of the type of innovation on the relationship between IC and innovation performance? The models generated in this publication showed that the type of innovation altered the relationship between IC and innovation performance. Two main differences between product/service and managerial innovation deserve special attention. On the one hand, managerial innovations entail changes in the inner workings of a company (Teece 1980; Damanpour & Aravind 2012) and thus, they benefit from knowledge codification. Accordingly, in

publication 2, the influence of structural capital on innovation was more relevant in the case of managerial innovation than in product/service innovation.

On the other hand, product/service innovation presents an external-to-the-firm approach as novelties must satisfy customers, while managerial innovation should improve internal processes and administrative systems (thus showing an internal-to-the-firm approach) (Damanpour & Aravind 2012). Consequently, while a boost in product/service innovation was proven to depend on external relational capital, the connection between internal relational capital and managerial innovation did not work as expected. An explanation for this surprising finding could be, as with the technology level, the lack of other contingencies being analysed in conjunction with the type of innovation. In other words, other contingency variables could be altering the influence of internal relational capital on managerial innovation performance.

Publications 3 and 4 answered the last sub-question: How do traditional and new IC components interact with each other to generate innovation performance? Both publications demonstrated that certain knowledge-related assets not included in the traditional framework deserve attention. Current companies that operate in a globalised and increasingly competitive environment, ruled by fast advances in technology and the leading role of the internet (OECD 2015a; OECD 2015b) are likely to need other knowledge resources not so urgently required in the past. In publications 3 and 4, the role of traditional IC components as antecedents of entrepreneurial and renewal capital was proved. Along with the results obtained, it could be the case that both entrepreneurial and renewal capital are more elaborated knowledge resources that build upon traditional IC components. However, as the inverse relationship was not tested, this discussion remains wide open. Another major issue that publications 3 and 4 demonstrated is the varying influence of traditional IC components on innovation performance depending on the presence of entrepreneurial and renewal capital. Overall, when new IC components were included in the model, traditional ones were likely to have an indirect impact on innovation performance, thus highlighting the relevance of entrepreneurial and renewal capital as innovation enhancers. It can be gleaned from both publications that innovation performance is better explained through combinations of traditional and new IC components, rather than by considering only the three-component framework.

5.2 Theoretical contribution

5.2.1 Contribution to the literature on IC

The main contribution of this dissertation falls under the literature on IC, which in turn belongs to the RBVs and KBVs of the firm. Hence, any contribution to the IC literature adds to the aforementioned views. However, as the study focuses on IC components, leaving aside other kinds of resources, such as tangible assets, it is argued that the dissertation contributes to the literature on IC.

Within the IC literature, out of the two main research streams (i.e. measuring, accounting and reporting IC; and creating, leveraging and managing IC [Roos et al. 1997]), the study focused on creating, leveraging and managing IC. This stream evolved through a first stage focusing on the measurement models of IC and moved towards a second stage which investigated the IC antecedents of performance (Martin-de-Castro et al. 2011).

Since this study analysed the role of new IC components and examined the IC antecedents of innovation, the exact contribution of the dissertation falls under both stages of the research stream devoted to creating, leveraging and managing IC. The remainder of this section discusses how this dissertation can add to the first stage of development in the IC research, and section 5.2.2 examines the contribution to the second stage.

This study contributed to the discussion about the measurement models of IC since it analyses the existence of IC components other than traditional ones. Since the first stage of the IC research during the 1990s, the competitive environment in which companies try to survive has changed dramatically. It is therefore likely that firms' needs in terms of IC stocks have also changed to adapt to the current globalised, highly competitive and internet-based environment, dominated by constant advances in technology (OECD 2015a; OECD 2015b). Contrasting with the widely held assumption that IC is composed by human, organisational or structural, and relational or social capital (Bontis 1996; Sveiby 1997; Bontis 1998; Subramaniam & Youndt 2005), the results endorse the idea that certain knowledge-related assets are largely underrepresented by the traditional three-component framework. While human, structural and relational capital represent a vital part of the knowledge stocks of a firm, entrepreneurial and renewal capital have also become relevant in current organisations. Consequently, the dissertation adds to the IC literature by demonstrating the need to expand the traditional three-component framework to include entrepreneurial and renewal capital; by so doing, this dissertation suggests a potential new stage of development in IC research which revisits the knowledge resources operating in companies.

5.2.2 Contribution to the literature on how IC influences innovation

This study contributes to the analysis of how IC enhances performance, and more precisely, to the discussion about the IC-related antecedents of innovation. The literature review offers a critical examination of the IC–innovation research field. Since the seminal article published by Subramaniam and Youndt (2005), this field of research has received considerable attention; however, literature needed a thorough examination. This literature review adds to the debate about how IC influences innovation by identifying the main insights of the IC–innovation research field, by providing a thorough critique of the literature, and by uncovering pertinent research gaps that could guide future studies on this field.

The empirical papers developed contribute to the field by adding new IC components to the study of the IC–innovation linkage and by incorporating a contingency approach to the discussion. In terms of the new IC components, the study showed that innovation is better explained through the interaction among traditional and new IC components. While past literature conceived innovation as being influenced by either human, structural or relational capital, or a combination of these (Wu et al. 2007; Wu et al. 2008; Hsu & Fang 2009; Carmona-Lavado et al. 2010; Leitner 2011; Carmona-Lavado et al. 2013), this dissertation included entrepreneurial and renewal capital. This goes along with previous attempts to incorporate new IC components into the study of the antecedents of company performance and value creation (Kianto et al. 2013; Kianto et al. 2014; Cesaroni et al. 2015).

As for the contingency perspective, this study expands existing literature by examining the specificities surrounding the IC–innovation linkage. Although a discussion about the contingency perspective was launched by Subramaniam and Youndt (2005) and Reed et al. (2006), more than a decade later, it remains underexplored. So far, academic research has focused on demonstrating that IC is a pertinent enhancer of innovation (e.g. Subramaniam & Youndt 2005; Carmona-Lavado et al. 2013; Delgado-Verde et al. 2015; Elsetouhi et al. 2015). Based on this well-demonstrated relationship, the current study explored the impact of two contingencies (i.e. technological sophistication and type of innovation) on the IC–innovation linkage. The findings showed that both technological sophistication and type of innovation affect the relationship between IC and innovation. The results also brought to the fore the complex behaviour of both contingencies because of the interactions among IC components, the influence of several characteristics on the same component and the lack of research that might reveal other pertinent characteristics and more contingency variables. Therefore, this study contributes to the almost forgotten debate about the contingency approach and opens an avenue for further research on the behaviour of technology level and type of innovation, as well as other contingency variables identified in the literature review such as size, industry and location.

5.3 Managerial implications

As the literature review highlighted, academic research and business practitioners are disconnected in terms of how IC influences innovation. Offering valuable prescriptions for managers is therefore a relevant part of this dissertation. Managers who want to strengthen IC in their companies, might find the SLR a useful starting point to become familiar with the IC–innovation research field. Even though it is a theoretical review of academic publications, business practitioners reading it could find themselves as tourists in a new city checking the map and identifying relevant places to visit.

Bearing in mind that technological sophistication and type of innovation affect the relationship between IC and innovation, it is highly recommendable that business practitioners adopt targeted IC management. As opposed to one-size-fits-all approach, a targeted IC management allows practitioners to implement those specific practices that better enhance IC, and subsequently innovation, in their organisations. Therefore, depending on the technology level of the firm, the type of innovation to be promoted and the IC components that want to be boosted, managers can find their own suitable path (see Table 11). As the models built are not exhaustive but constitute a worthwhile road map for improving innovation in a resource constrained environment, companies could use these models for increasing their understanding of which IC components are advisable to work on to obtain better innovation results. Thus, by knowing the inside game for boosting innovation performance in certain situations, managers can decide where to allocate their limited resources.

Table 11: Targeted IC management

	High-tech	Low-tech
Product/Service innovation	**IC components considered:** - Human capital - Structural capital - Internal relational capital - External relational capital **Main significant relationships:** Human → innov. Ext. relational → innov. **Model:** *Figure 13: Product/service innovation in high-tech firms – Publication* 2	**IC components considered:** - Human capital - Structural capital - Internal relational capital - External relational capital **Main significant relationships:** Structural → innov. Ext. relational → innov. **Model:** *Figure 14: Product/service innovation in low-tech firms – Publication* 2
Managerial innovation	**IC components considered:** - Human capital - Structural capital - Internal relational capital - External relational capital **Main significant relationships:** Int. relational → human → innov. Ext. relational → human → innov. Int. relational → structural → innov. **Model:** *Figure 17: Post-hoc model – Managerial innovation in high-tech firms – Publication* 2	**IC components considered:** - Human capital - Structural capital - Internal relational capital - External relational capital **Main significant relationships:** Human → structural → innov. Int. relational → structural → innov. Ext. relational → structural → innov. **Model:** *Figure 18: Post-hoc model – Managerial innovation in low-tech firms – Publication* 2
Overall innovation	**IC components considered:** - Human capital - Entrepreneurial capital - Renewal capital **Main significant relationships:** Human → entrepreneurial → innov. Human → renewal → innov. Entrepreneurial → renewal → innov. **Model:** *Figure 20: Model for high-tech firms – Publication* 3	**IC components considered:** - Human capital - Entrepreneurial capital - Renewal capital **Main significant relationships:** Human → entrepreneurial Human → renewal → innov. Entrepreneurial → renewal → innov. **Model:** *Figure 21: Model for low-tech firms – Publication* 3
	IC components considered: - Structural capital - Internal relational capital - External relational capital - Renewal capital **Main significant relationships:** Structural → renewal → innov. Int. relational → renewal → innov. Ext. relational → renewal → innov. **Model:** *Figure 23: Model for high-tech firms – Publication* 4	**IC components considered:** - Structural capital - Internal relational capital - External relational capital - Renewal capital **Main significant relationships:** Structural → innov. Int. relational → innov. Ext. relational → innov. Structural → renewal → innov. Int. relational → renewal → innov. Ext. relational → renewal → innov. **Model:** *Figure 24: Model for low-tech firms – Publication* 4

Notes: innov.: innovation performance; int.: internal; ext.: external.

It is advisable that companies perform an IC audit to know the degree of development of each component of IC. The scales used in this dissertation might be useful in this regard. As the dissertation considered both entrepreneurial and renewal capital, it provides a comprehensive representation of the IC components that are more likely operating in

current companies. This audit could show to the board the current position of the components of IC and promote a deeper understanding of the specificities of the IC–innovation relationship (see Table 11), which could help to make informed decisions about which component it is appropriate to work on. As the models tested demonstrate, all the IC components considered could contribute to innovation; thus, the following paragraphs present some ideas for strengthening each IC component.

As human capital is the soul of the company (Roos et al. 1997, p.34), it is vital to be aware of employees strengths and limitations in terms of qualification, skill base and motivation. Those companies that can monitor the evolution of their employees and satisfy their needs will have a priceless advantage for innovation.

Regarding structural capital, managers should attempt to build databases and information systems that adapt to the inner workings of the company, rather than the reverse. Using the most up-to-date technology to build complex databases and information systems is not always the right choice. As structural capital is the knowledge tool-box of the organisation and each corporation is different, each one must find the proper structures that support their everyday activity.

In terms of internal relational capital, managers should abandon the well-known idea that trustable relationships among employees promote innovation. This dissertation has shown that this mantra does not always work, as in the case of creating new products and services in both high-tech and low-tech companies. However, for those situations in which internal relations need to be enhanced, having deep knowledge about employees is highly useful. Managers should foster an atmosphere of trust, in which employees feel that their ideas are worthwhile and that teamwork is desired rather than imposed.

Turning to external relational capital, the models developed herein found no other IC component fostering it. Hence, some suggestions for strengthening external relational capital will be shared. The industry in which the firm operates could play an important role since some industries are particularly active in terms of organising events, conferences and workshops where professionals can gather, share ideas and build a solid network. Moreover, for maintaining close relationships with customers, it is strongly advised to determine what they want beyond the mere product or service the company is selling. Nowadays, customers have the chance to buy almost the same product or service from a wide variety of firms; thus, the company that understands and takes care of its customers' inner needs has a great advantage over its competitors.

Because entrepreneurial capital is concerned with the identification of opportunities, and the ability to take risks and to make difficult decisions, the internal atmosphere of the firm is of utmost importance. Employees will never share a new idea, nor they will make a hard and risky decision in a company that severely penalises error. As for fostering internal relations, having a trustable atmosphere in which managers explicitly encourage people to think beyond the boundaries of their current products and services is a vital ingredient for entrepreneurial capital. In addition, as publication 3 shows, fostering individual qualification and motivation is also a crucial enhancer of entrepreneurial capital.

Finally, fostering renewal capital relates to enhancing human, structural, internal relational, external relational and entrepreneurial capital. The models tested have demonstrated that by strengthening these other IC components, renewal capital could be benefited. Thus, in a resource-constrained situation, companies might find it advantageous to concentrate their efforts on having a well-qualified and motivated workforce, useful databases and information systems, trustable networks of relationships both internal and external to the firm and well-developed entrepreneurial capabilities. As change is not always welcome, companies might be reluctant to renew their knowledge bases. Motivating employees (human capital) and fostering employees to develop new ideas and assume risks (entrepreneurial capital) are extremely important.

5.4 Limitations and future research

The research presented has several limitations that give rise to future research opportunities. Even though the innovation metric included all five types of innovation recognised by the Oslo Manual, one sole indicator represented each innovation type. Moreover, innovation was mainly measured according to the results obtained, and these metrics are not usually combined with others related to the process of innovating, the degree of radicality and the desire to innovate. This view excessively centred in the results of innovation could lead to a partial understanding of the innovation phenomenon. As Tidd and Bessant (2009, p.16) recognised, 'If we only understand part of the innovation process, then the behaviours we use in managing it are also likely to be only partially helpful – even if well intentioned and executed'. It is therefore recommendable to complete the way of measuring innovation so that the paths conducive to enhancing it could be even more accurate.

Another limitation emerges from the sample of companies as it was limited to Spanish firms. It could be the case that some of the findings were affected by specific national characteristics, such as culture, economic climate and political situation. Future research could test the models in other national contexts and compare the results obtained. Moreover, although the sample of firms included 180 companies, answers were provided by one person in each firm. This could lead to common method bias. To ensure that the data analysed were not damaged, Harman's one-factor test (Podsakoff & Organ 1986) was conducted, and the results discarded a common method bias.

As explained, the level of analysis used in this dissertation limits the results. This research analyses IC at the company level, while the knowledge used by employees of different functional or knowledge areas could also differ. Therefore, future studies could take the models developed in this research as a starting point when determining the specificities of the IC–innovation linkage for employees in various functional or knowledge areas.

In addition, the research strategy applied constitutes another limitation. As different strategies address reality in one way or another (Bryman & Bell 2011), choosing one strategy over another always entails problems. In the case of this dissertation, a quantitative strategy was selected and a questionnaire was used for collecting the data. Apart of the risk of common method bias already explained, the questionnaire used proxies for measuring IC and innovation performance. Even though the questionnaire was developed as part of a project funded by a renowned institution and the same questionnaire was applied in other publications, it is always a concern as to what extent

proxy measures can represent the variables (Bryman & Bell 2011). Moreover, as some publications offered unexpected findings that are hard to explain, it might be commendable to carry out qualitative case studies to delve further into the IC–innovation linkage and adopt a longitudinal approach that captures data at several points in time.

The last limitation concerns the contingency variables included. Technological sophistication and type of innovation have proven to be pertinent contingencies in the IC–innovation linkage. Nevertheless, as the literature review suggests, there might be other contingencies such as size, industry and location, that deserve special attention. Additionally, the complex behaviour of both technology level and type of innovation highlighted the need for further research on the characteristics that differ between high- and low-tech companies and various innovation types.

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Publication 1

Buenechea-Elberdin, M.

Structured literature review about intellectual capital and innovation

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Structured literature review about intellectual capital and innovation

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Abstract

Purpose – The purpose of this paper is to review and critique the literature dealing with the relationship between intellectual capital (IC) and innovation, and to outline the future of this research field.
Design/methodology/approach – Structured literature review (SLR).
Findings – The relationship between IC and innovation has been examined in great detail; however, much remains to be understood regarding the way of approaching and conceptualising both IC and innovation according to the current business environment. Moreover, academic literature on the IC-innovation relationship shows a disconnection between academia, and both business practice and policy-making, in this research domain.
Research limitations/implications – Since the study was developed by one person, the results could be influenced by her subjective interpretation. In addition, only journal articles published between 2006 and 2015 have been examined.
Originality/value – This paper contributes to IC literature by providing a unique SLR of the IC-innovation field of research. The paper points to pathways for future research in the IC-innovation domain.

Keywords Innovation, Intellectual capital, Structured literature review
Paper type Literature review

Introduction

Continuous innovation has become a key requirement for organisational viability in the present environment characterised by fierce competition and increasing globalisation (Chen *et al.*, 2010; Kianto, 2011). As Sáenz and Aramburu (2011, p. 87) point out, innovation "is a matter of survival in a free market economy" and therefore, the creation of something new (i.e. innovation) is no longer an optional choice but a necessity facing all organisations alike. Accordingly, finding ways to maintain the requisite level of renewal and developing capabilities for being more creative and innovative have become imperatives for firms.

Intellectual capital (IC), the set of intangible assets that the firm owns or has access to (Edvinsson and Malone, 1997) has been at the forefront of a wide range of studies in the management field. Embedded within the resource-based view of the firm (Wernerfelt, 1984; Barney, 1991), building strong intangibles provides companies with opportunities for improving business performance (Mention and Bontis, 2013), gaining competitive advantage (Chahal and Bakshi, 2015) and innovating (Wu *et al.*, 2007; Leitner, 2011). Traditionally, IC has been split into three components: human capital (HC) or employees' knowledge, skills and experience (Schultz, 1961; Subramaniam and Youndt, 2005); structural capital (SC) or firms' codified knowledge, databases and culture (Bontis, 1996; Menor *et al.*, 2007); and relational capital (RC) or the knowledge embodied in the networks of internal and external relationships the company manages (Nahapiet and Ghoshal, 1998; Hsu and Fang, 2009; Bontis, 1998; Subramaniam and Youndt, 2005).

The existing literature has repeatedly demonstrated the connection between IC and innovation (Subramaniam and Youndt, 2005; Wu *et al.*, 2007; Hsu and Fang, 2009;

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Leitner, 2011). However, the sheer amount of the existing studies as well the varying methodological choices and approaches taken by different authors to both IC and innovation, beg the question of where the IC-innovation research field currently stands as a whole. As innovation is essential for company survival, gaining a deep and holistic understanding of how this field of research has evolved so far and where it should go from here is of utmost importance. Comprehending what is known about the IC-innovation relationship is significant for both academics, aiming to grasp potential research opportunities, and managers, looking for insights into how to reinforce innovation in their organisations.

To provide an overall appreciation of the development of a research field, a thorough review of the existing literature is needed. However, there are not previous structured literature reviews (SLR) examining how the relationship between IC and innovation has been studied. Some reviews focus solely on IC, excluding the impact IC could exert on innovation (Dumay *et al.*, 2015; Ferenhof *et al.*, 2015). Other studies consider the influence of IC on organisational performance in general; however, they do not specifically concentrate on innovation as the dependent variable (Moustaghfir, 2009; Inkinen, 2015).

Consequently, this research aims to present a review and critique of the articles addressing the IC-innovation relationship published from 2006 to 2015, and to suggest future research lines. The choice of examining papers published in 2006 or later was made because the research on IC-innovation linkage took a noteworthy turn in 2005 with the appearance of a seminal article in the *Academy of Management Journal* by Subramaniam and Youndt "The influence of intellectual capital on the types of innovative capabilities". This paper is one of the most quoted articles on the research field, and at the time of writing this paper (19 December 2016) has been referenced 2017 times in Google Scholar publications.

The research questions posed are the following:

RQ1. How is research for inquiring into the IC-innovation relationship developing?

RQ2. What is the focus of the IC-innovation relationship literature?

RQ3. What is the future for the IC-innovation relationship literature?

The rest of the paper continues as follows: the next section explains the methodology used, which takes the form of an SLR (Massaro *et al.*, 2016). After that, the paper presents the findings, which are based on the insights and critique of the literature analysed. Then, the paper offers a discussion of the results obtained which provides answer to the third research question posed. Finally, limitations, implications and future research opportunities are presented.

Research method

This study follows the SLR method (Massaro *et al.*, 2016), which "complements traditional literature reviews because the approach helps to yield different outcomes that are defensible" (p. 769). In addition, "SLRs are attractive to researchers because they offer a history, some critique and outline the future research potential of particular domains" (p. 795). Hence, an SLR is the most appropriate methodology to conduct a reliable analysis of the literature linking IC and innovation, as well as to present a fair critique of this literature and to outline future research directions.

Following the SLR methodology, a review protocol was created to document the procedure followed. According to the purpose of the SLR, which is to present a comprehensive review of the articles addressing the IC-innovation relationship published from 2006 to 2015, the population to be studied included articles that were:

- empirical, because IC research should never be disconnected from practice (Petty and Guthrie, 2000) and because empirical papers analysing one or several companies are the most suitable for developing a better understanding of business practice;

- published in peer-reviewed journals, which guarantees a high level of quality as a consequence of the strict refinement process inherent in publication;
- published from 2006 to 2015, as the seminal paper in this field of research was published in 2005 by Subramaniam and Youndt;
- concerned with the IC-innovation relationship, because continuous innovation is a crucial requirement for companies (Chen *et al.*, 2010; Kianto, 2011) and IC is one of its main antecedents (Subramaniam and Youndt, 2005); and
- written in English, since English is the official language of academia.

The selection of papers was conducted using the primary academic databases of Scopus, EBSCO, Web of Knowledge (WOK) and Google Scholar in order to guarantee the inclusion of all articles fulfilling the abovementioned criteria. An initial search of the Scopus, EBSCO and WOK databases (title, abstract and keywords field) was conducted using the keywords "intellectual capital" and "innovation". The results obtained (189 in Scopus, 236 in EBSCO and 90 in WOK) were then refined by analysing their titles and abstracts. This step yielded a total of 54 articles. Then, Google Scholar Metrics were used to identify the top publications in several categories (list below (Metrics in Google Scholar – top publications)) related to the field of study. After checking each of the journals contained in the aforementioned categories, it was verified that all the journals were either already considered by Scopus, EBSCO and/or WOK for the period 2006-2015; or were predatory journals, according to the well-known list published by Jeffrey Beall (https://scholarlyoa.com/). Hence, an additional search of Google Scholar was deemed unnecessary at this point.

Metrics in Google Scholar – top publications:

Categories

- business, economics and management;
- business, economics and management (general);
- entrepreneurship and innovation;
- human resources and organisations;
- international business;
- marketing;
- strategic management; and
- tourism and hospitality.

At that stage, a key concern emerged related to the use of the keyword "innovation" instead of the keywords "innovating", "innovate" or "develop a new product", among others. Since "Innovation is a broad term with multiple meanings" (Crossan and Apaydin, 2010, p. 1165), it was possible that there were relevant studies that used different reference terms. Therefore, the search of Scopus, EBSCO and WOK was repeated using the following search string: "intellectual capital" AND "innov*" OR "new product" OR "new service" OR "new process" OR "new management" OR "new marketing" OR "new market" OR "new practice". Since this new search extended the previous one, most of the results obtained (236 in Scopus, 256 in EBSCO and 98 in WOK) had already been analysed. After checking the titles and the abstracts of the new references, 11 articles were added to the existing list of selected papers. Then, a list of journals referring to the selected papers was prepared, and Scopus, EBSCO and WOK were searched to be sure that the journals were completely covered for the period from 2006 to 2015. Since some years were missing, Google Scholar was searched for these specific missing years, but no additional papers were discovered.

Finally, the full text for all of selected papers was reviewed in order to make the final decision about their inclusion in the list, and 40 articles were considered. Since the review was conducted by only one researcher, a second verification round was performed using the list containing 236 Scopus references, 256 EBSCO papers and 98 WOK articles. This second review yielded the same list of 40 articles; hence, this is the list of papers analysed in this SLR (Table AI).

Following the comprehensive literature search, the impact of the articles that fit the established criteria was tested. Both the total number of citations and the citations per year (CPY) were calculated. The results (Tables I and II) show that, with a couple of exceptions, the two lists are similar, meaning that the list of relevant papers is nearly the same in terms of total citations and CPY.

The analytical framework (Table III) was developed in accordance with previous literature. Due to space limitations, the reasons supporting the inclusion of each category will be directly explained in the findings section. Nvivo was used for the manual codification.

Findings

This section presents and critically analyses the insights of the IC-innovation literature. In other words, it answers the two first proposed research questions:

RQ1. How is research for inquiring into the IC-innovation relationship developing?

RQ2. What is the focus of the IC-innovation relationship literature?

Author type

Although IC research emerged from practice (Petty and Guthrie, 2000), 92.5 per cent of studies have been conducted by academics. By comparison, practitioners have contributed only 2.5 per cent of studies, and academic-practitioner collaborations have produced 5 per cent of studies. The scarcity of practitioner contributions threatens the link between

Year	Authors	Title	Total citations	Position as CPY
2009	Hsu and Fang	Intellectual capital and new product development performance: the mediating role of organizational learning capability	269	1
2008	Wu *et al.*	Promoting innovation through the accumulation of intellectual capital, social capital, and entrepreneurial orientation	208	2
2006	Chen *et al.*	The influence of intellectual capital on new product development performance – the manufacturing companies of Taiwan as an example	133	7
2010	Carmona-Lavado *et al.*	Social and organizational capital: building the context for innovation	109	4
2007	Menor *et al.*	Examining the influence of operational intellectual capital on capabilities and performance	86	9
2011	Cabello-Medina *et al.*	Leveraging the innovative performance of human capital through HRM and social capital in Spanish firms	85	5
2007	Wu *et al.*	Intellectual capital, dynamic capabilities and innovative performance of organisations	76	11
2011	Delgado-Verde, Castro and Navas-López	Organizational knowledge assets and innovation capability: evidence from Spanish manufacturing firms	71	6
2008	Zerenler *et al.*	Intellectual capital and innovation performance: empirical evidence in the Turkish automotive supplier	66	12
2013	Martín de Castro *et al.*	The moderating role of innovation culture in the relationship between knowledge assets and product innovation	65	3

Table I. Top ten articles by total citations

Table II. Top ten articles by citations per year (CPY)

Year	Authors	Title	CPY	Position as total citation
2009	Hsu and Fang	Intellectual capital and new product development performance: the mediating role of organizational learning capability	38.43	1
2008	Wu *et al.*	Promoting innovation through the accumulation of intellectual capital, social capital, and entrepreneurial orientation	26.00	2
2013	Martín de Castro *et al.*	The moderating role of innovation culture in the relationship between knowledge assets and product innovation	21.67	10
2010	Carmona-Lavado *et al.*	Social and organizational capital: building the context for innovation	18.17	4
2011	Cabello-Medina *et al.*	Leveraging the innovative performance of human capital through HRM and social capital in Spanish firms	17.00	6
2011	Delgado-Verde, Castro and Navas-López	Organizational knowledge assets and innovation capability: evidence from Spanish manufacturing firms	14.20	8
2006	Chen *et al.*	The influence of intellectual capital on new product development performance – the manufacturing companies of Taiwan as an example	13.30	3
2011	Lee *et al.*	The roles of worker expertise, information sharing quality, and psychological safety in manufacturing process innovation: An intellectual capital perspective	9.80	11
2007	Menor *et al.*	Examining the influence of operational intellectual capital on capabilities and performance	9.56	5
2011	Hsu and Sabherwal	From intellectual capital to firm performance: the mediating role of knowledge management capabilities	8.80	12

research and practice in this domain. This topic will be further explored when analysing the practical implications.

Among the 78 authors involved in the included studies, 65 (83.33 per cent) have written only one article in the field; this suggests a lack of continuity in research on the specificities of the IC-innovation relationship. As Table IV shows, most of the authors who have written more than one article are Spanish researchers who tend to collaborate together (as the "group" column indicates). Researchers belonging to Group 1 have been very active in publishing on IC and innovation. Though the active contributions of these researchers should not be criticised, it is important to consider the possibility of their work dominating the evolution of the research field.

In addition, 90 per cent of the articles have been developed by groups of two, three or four authors (Figure 1); thus, collaboration appears to be a normal practice in this field of research.

Location of the sample of firms

The firms' locations have been grouped according to a recent SLR (Massaro *et al.*, 2016). The relevance of the locations of the sample of firms lies in the fact that cultural differences among countries affect autonomy and social relations, among other issues; thus, IC differs from one country to another (Hofstede *et al.*, 2010). According to Inkinen (2015), empirical IC papers have not equally covered all relevant locations. Asia (16 articles) and Europe (15 articles) are the preferred scenarios, and work in these areas comprises 77.5 per cent of the papers. Within Asia, Taiwan and China (eight and four articles each) are the most popular locations, while, in Europe, Spain accounts for 27.5 per cent (11 papers) of all articles. Hence, in the entire world, 23 out of the 40 articles (57.5 per cent) focus on only three countries.

Category	Variables	Results
Author type	Academic/s	37
	Practitioner/s	1
	Academic/s and practitioner/s	2
	Total	40
Location of the sample of firms	EU	15
	UK	0
	North America	4
	Central America	1
	South America	1
	Australia and New Zealand	1
	Asia	16
	Africa	2
	Total	40
Industry of the sample of firms	Manufacturing	21
	Services	6
	Manufacturing and services	11
	Not explained	2
	Total	40
Technology level of the sample of firms	High technology	20
	Low technology	6
	High and low technology	8
	Not explained	6
	Total	40
Size of the companies	SMEs	5
	No SMEs	32
	Combination	3
	Total	40
Research methods	Quantitative	37
	Qualitative	2
	Mixed	1
	Total	40
Quantitative research methods	Basic statistics	3
	Regression analysis	17
	Regression and PLS	1
	Partial correlation and SEM	1
	Structural equation model (SEM)	16
	Total	38
Qualitative research methods	Action research	1
	Case study	1
	Interviews	1
	Total	3
IC components and combinations	Human	1
	Human, structural	2
	Human, social	1
	Human, social networks	1
	Structural	2
	Organisational	1
	Social, organisational	2
	Relational, social	1
	Supplier and customer relationship	1
	Human, relational, structural	10
	Human, structural, social	2
	Human, organisational, social	6
	Human, organisational, customer	1

(*continued*)

Table III. Framework

Category	Variables	Results
	Human, customer, structural	1
	Human, organisation, information	1
	Employee, structural, customer	1
	Human, structural, external social, internal social	1
	Human, social, customer, organisational	1
	Human, technological, customer/relational	1
	Human, technological knowledge, innovation culture	1
	Human, relational, structural, entrepreneur human capital	1
	Internal IC and external IC	1
	Total	40
Innovation	Innovation as a result	26
	Output	6
	Product	4
	Product/service and process	1
	Product, process and managerial	1
	Outcome	8
	Product	5
	Process	1
	Not explained	2
	Output and outcome	11
	Product	8
	Product and process	1
	Product, process and managerial	1
	Product/service, process, technology and managerial	1
	Output and radical	1
	Product and process	1
	Degree of radicality	6
	Product/service	1
	Product/service and process	2
	Product, process and technology	1
	Not explained	2
	Innovation as a process	5
	Capability to innovate	4
	Innovation as a process	1
	Innovativeness	3
	Total	40
Research questions and hypotheses	Provides research question	1
	Provides hypothesis	30
	Provides research question and hypothesis	6
	Neither research question nor hypothesis	3
	Total	40
Findings	Provides research findings	40
	Research findings not provided	0
	Total	40
Research implication	Provides research implication	37
	Research implication not provided	3
	Total	40
Practical implication	Provides practical implication	32
	Practical implication not provided	8
	Total	40
Policy implication	Provides policy implication	2
	Policy implication not provided	38
	Total	40
Subramaniam and Youndt (2005)	Cites Subramaniam and Youndt (2005)	31
	Do not cite Subramaniam and Youndt (2005)	9
	Total	40

Table III.

Group	Authors	Amount of papers
1	Delgado-Verde, M.	7
1	Martín de Castro, G.	6
1	Navas-López, J.E.	6
1	Amores-Salvadó, J.	4
1	Cruz-González, J.	2
2	Cabello-Medina, C.	3
2	Carmona-Lavado, A.	2
2	Cuevas-Rodríguez, G.	2
3	Aramburu, N.	2
3	Sáenz, J.	2
4	Chien, S.-H.	2
5	Costa, R.V.	2
5	Fernández-Jardon, C.	2

Table IV. Authors

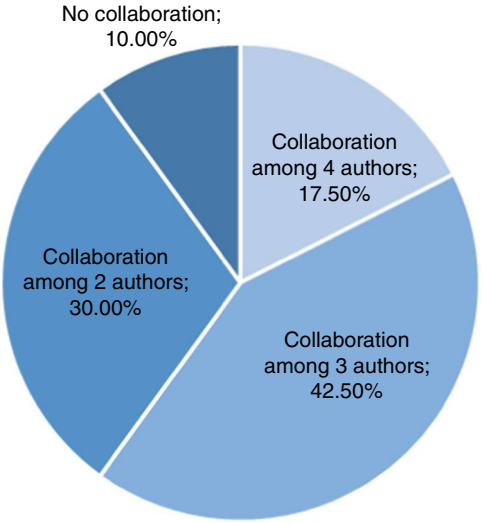

Figure 1. Collaboration among authors

Despite this concentration of research on Europe and Asia, in the last couple of years (2014 to 2015), articles focussed on Central and South America (one article each) and Africa (two articles) have been published, resulting in these locations' first appearance in the field. Therefore, there is a recent trend towards breaking the hegemony of Europe and Asia in favour of new locations (Figure 2).

Industry of the sample of firms

The category of industry is included because both IC and innovation differ between manufacturing and service companies (Hipp and Grupp, 2005; Kianto *et al.*, 2010). Contrary to expectations, among the articles combining companies from both industries (27.5 per cent), there is no study comparing how the IC-innovation connection works differently in manufacturing and service companies. In addition, a large proportion of articles is devoted to manufacturing firms (52.5 per cent), whereas service companies are clearly under-represented (15 per cent). Figure 3 shows how the evolution of the number of articles in this field has been shaped by the evolution of the articles addressing

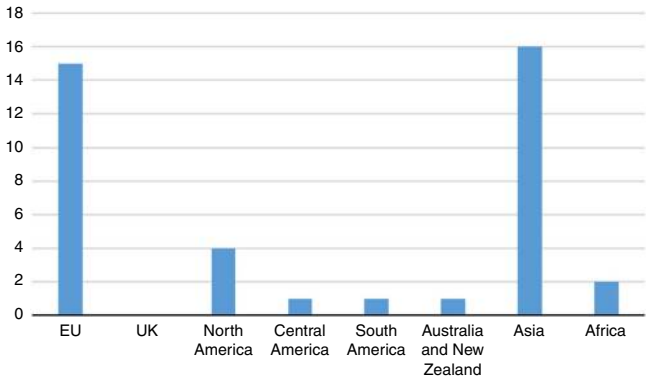

Figure 2.
Location of the sample of firms

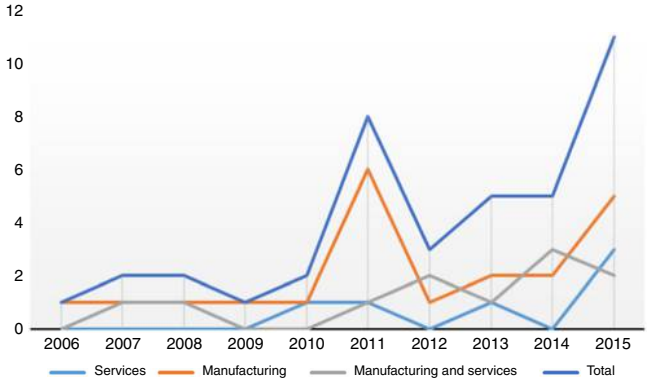

Figure 3.
Manufacturing and services

manufacturing companies. Since both IC and innovation differ between manufacturing and service firms (Hipp and Grupp, 2005; Kianto *et al.*, 2010), on one hand, and since the service sector is both relevant and highly reliant on knowledge resources (Kianto *et al.*, 2010), on the other, more research should be done to understand the specificities of the IC-innovation relationship within the service sector. In fact, there seems to be an emerging trend towards analysing service companies, since four out of the six articles dealing with the service sector were published from 2013 to 2015.

Technology level of the sample of firms

The companies' technology levels were determined using the Organisation for Economic Co-operation and Development (OECD) and Eurostat classification approach. Following this approach, companies were sorted according to their average values, as compared to aggregate OECD R&D intensities (R&D expenditure divided by value added and R&D expenditure divided by production), from 1991 to 1999. High and medium-high technology firms obtained above average values for both indicators, and the contrary applies to low and medium-low technology firms (OECD, 2011).

According to De Carolis (2010) and Schilling (2011), the knowledge present in high-tech and low-tech companies varies significantly in terms of complexity level (i.e. the underlying components and the interdependencies among components), tacitness (i.e. knowledge is more tacit in high-tech firms) and pace of renovation (i.e. high-tech companies need to

constantly update their knowledge base). Since IC reflects the knowledge resources managed by the firm (Subramaniam and Youndt, 2005), changes to technology levels produce a different configuration of IC components.

There seems to be particular research interest in firms belonging to high-tech industries (50 per cent). However, only seven of these 20 articles explicitly refer to "high-technology" sectors. Though the remaining 13 articles deal with high-tech firms, they do not explicitly reference to the technology levels of their samples of companies; thus, there is no clear evidence about their intention to address firms belonging to high-tech industries.

In addition, low-tech industries are clearly under-represented (six articles), and none of the papers focussed on high- and low-tech companies (eight articles) make a comparison of how the IC-innovation linkage works among companies with different technology level.

Consequently, though there is a connection between the knowledge managed by a company and its technology level (De Carolis, 2010; Schilling, 2011), technology level has not been widely considered as an important factor in existing research.

Size of the companies

In 1998, Greiner (as cited in Cohen and Kaimenakis, 2007, p. 241) asserted that "firms of relatively small size follow a different model of organizational practices when compared to large corporations". Large and small companies are expected to have varying needs in terms of their ways of organising business and accumulating knowledge. In addition, innovation capacity changes according to company size, as large firms (in comparison to small ones) own more resources and have more hierarchical layers, among other characteristics (Nooteboom, 1994).

Since ways of understanding small- and medium-sized (SME) enterprises differ across countries and researchers (Massaro *et al.*, 2016), it is difficult to identify SMEs unless authors explicitly refer to them. For our purposes, since this study does not focus on the specific characteristics of SMEs and since studies addressing SMEs tend to state this explicitly, only those studies that explicitly reference the term "SME" are classified into the "SMEs" group.

The results reinforce the common belief that IC research has primarily analysed big companies (Cohen and Kaimenakis, 2007; Tovstiga and Tulugurova, 2007), since 80 per cent of the papers do not explicitly address SMEs. However, there seems to be a recent trend towards focussing on SMEs, since four out of the five studies belonging to this category were published in 2014 and 2015.

Research methods

The category of research methods is included because research methods "are not simply neutral tools: they are linked to the ways in which social scientists envision the connection between different viewpoints about the nature of social reality and how it should be examined" (Bryman and Bell, 2011, p. 4). Hence, the choice of research method illustrates a researcher's way of understanding reality and reveals specific aspects of the complex reality for analysis.

Petty and Guthrie (2000) noted that there is a lack of studies adopting multi-method approaches that combine quantitative and qualitative techniques. However, it appears that researchers have not responded to this call, since only one study adopted a mixed approach. Overall, 92.5 per cent of the papers applied quantitative methods, and 5 per cent used qualitative methods. Of the quantitative techniques, regression analysis (44.74 per cent) and structural equation modelling (42.11 per cent) were the most popular. This over-representation of quantitative methods simplifies the reality of the research field, since quantitative research understands topics from a positivistic approach, in which researcher aims to test theories and develop laws (Bryman and Bell, 2011). Thus, the current body of literature is lacking a deeper interpretation of reality that cannot be generalised, but that respects and enhances individual specificities (i.e. interpretivism) (Bryman and Bell, 2011).

IC components and combinations

Although Subramaniam and Youndt (2005) present IC as comprising human, organisational and social capital, the IC components explained here are all of the ones present in the analysed articles. In other words, though the aforementioned seminal paper proposes a specific IC framework, this study has collected all of the components identified in each of the 40 studies as "IC components". This approach facilitates the analysis of different nomenclatures and combinations. The performed analysis places special attention on the terminology applied, so that different groups have been created according to the specific terms utilised.

The analysis reveals that IC components have been understood and combined in different ways, resulting in a diverse set of possibilities. Of the total set of articles, only 10 per cent target one component; the remainder combine two (20 per cent), three (60 per cent) or more components (10 per cent) to analyse their interactions and synergies when influencing innovation.

The most preferred IC combinations are human, relational and structural (ten articles) and human, organisational and social (six articles). Overall, 40 per cent of the articles apply the traditional three-dimensional IC framework (Bontis, 1998; Subramaniam and Youndt, 2005), thus reinforcing the relevance of this framework among IC-innovation studies. Moreover, among the studies adopting the traditional terminology, human (21.18 per cent), structural (18.18 per cent), social (11.82 per cent), relational (10.91 per cent) and organisational (10 per cent) are the most-used terms (Table V). In addition, as Table V shows, all of the utilised terms, with the exception of "Entrepreneur HC", which views HC from a slightly different perspective by explicitly linking the entrepreneurship and IC literatures (Ugalde-Binda *et al.*, 2014), can be directly connected to the traditional IC framework (Bontis, 1998; Subramaniam and Youndt, 2005).

Table V. Classification into traditional IC framework

IC component	Amount of times it appears	% of times it appears (%)	Traditional framework
Human	31	28.18	Human capital (HC)
Employee	1	0.91	
Internal human	1	0.91	
External HC	1	0.91	
Entrepreneur HC	1	0.91	
Structural	20	18.18	Structural capital (SC)
Organisational	11	10.00	
Organisation	1	0.91	
Information	1	0.91	
Technological	2	1.82	
Innovation culture	1	0.91	
Internal structural	1	0.91	
External structural	1	0.91	
Social	13	11.82	Relational capital (RC)
Relational	12	10.91	
Customer	4	3.64	
Customer/relational	1	0.91	
Social networks	1	0.91	
External social	1	0.91	
Internal social	1	0.91	
Internal relationship	1	0.91	
External relationship	1	0.91	
Relationship with supplier	1	0.91	
Relationship with customer	1	0.91	

Consequently, opening the scope of study to collect all possible variables identified as IC components has reinforced the traditional three-dimensional framework, distinguishing three key components of IC: HC, SCSC and RC. However, this supremacy of the traditional IC components does not necessarily imply their usefulness. According to the OECD (2015), there are "key trends – the spread of global value chains, the increasing importance and mainstreaming of knowledge-based capital (KBC), and rapid technological progress, including the rise of the digital economy" which "are leading to the emergence of a 'next production revolution'" (pp. 2-3). These major changes are likely to have influenced the business environment and thus, it surprising that, around 18 years after its development (Edvinsson and Malone, 1997; Bontis, 1998), the traditional framework is still utilised as the main – and indeed the only – way of portraying the intangibles of a company.

In the following, several key remarks about each of the three groups (i.e. HC, SC and RC) will be shared. HC maintains essentially the same nomenclature across all articles. However, the way of understanding and measuring HC differs among papers, producing two main types of approaches: general and narrow. The general approach considers HC as referring to the knowledge, skills, qualification, expertise, motivation and creativity of employees (Hsu and Fang, 2009; Hsu and Sabherwal, 2011; Leitner, 2011; Elsetouhi *et al.*, 2015). By contrast, the narrow approach concentrates on a much more limited set of employee characteristics, such as their value and uniqueness (Cabello-Medina *et al.*, 2011), their abilities and attitude (Chien, 2010), or their skills and learning capabilities (Menor *et al.*, 2007), among others.

With respect to SC, the primary expressions used are structural and organisational capital, which have sometimes been applied interchangeably (Inkinen, 2015). Both structural and organisational capital refer to the knowledge codified, stored and utilised in the form of databases, written procedures and information systems (Menor *et al.*, 2007; Wu *et al.*, 2007; Carmona-Lavado *et al.*, 2013; Wang and Chen, 2013), as well as to licenses and corporate culture (Carmona-Lavado *et al.*, 2013). Other studies have shown the differences between the two terms, arguing that SC has a broader scope and combines both internal (i.e. organisational capital, comprising organisational design, culture, policies and innovation strategy and technological capital) and external structure (i.e. intangibles linked to external relations) (Aramburu and Sáenz, 2011; Aramburu *et al.*, 2015). In addition, organisational capital has also embraced the formal analysis of project success and failure, as well as the application of knowledge in new products (Carmona-Lavado *et al.*, 2010); and environmental policies, responsibilities and communication structures (Delgado-Verde, Amores-Salvadó, Martín de Castro and Navas-López, 2014). Furthermore, quality management systems, achieved efficiency, customer relationships, reputation and marketing (Leitner, 2011) have been linked to SC.

Several other expressions have also emerged in this field, such as technological capital (i.e. R&D efforts and the codification of knowledge (Castro *et al.*, 2013)), technological knowledge assets (i.e. non-protected knowledge and patents) (Martín-de Castro *et al.*, 2013), and innovation culture (i.e. experimentation, creativity and common values) (Martín de Castro *et al.*, 2013).

Attending to RC, relational and social capital are the most popular terms. The main distinction between these is their focus on internal or external relationships. In general, social capital tends to have an internal-to-the-firm approach (seven out of 13 studies referring to social capital focus on internal linkages). It concentrates on either the relational embeddedness (Nahapiet and Ghoshal, 1998) of employees' relationships networks (Cabello-Medina *et al.*, 2011) or the quality of the relationships among employees (Delgado-Verde, Navas-López, Cruz-González and Amores-Salvadó, 2011). By contrast, RC is likely to address relationships with external agents (eight out of 13 articles referring to RC cover linkages with external agents), such as customers, suppliers and strategic partners (Chen *et al.*, 2006; Hsu and Fang, 2009; Han and Li, 2015) or customers, academia,

support institutions and government (Ugalde-Binda *et al.*, 2014). While generally the papers utilising the social capital concept are likely to focus on intra-firm relationships and those speaking about RC tend to concentrate on external relations, there still are some papers that are using these concepts in other ways.

The various ways of defining and understanding the IC components lead to different manners in terms of operationalising the constructs, and thereby, what has been measured tends to differ even between those articles that claim to be examining identical IC components. This diversity surrounding the conceptualization of IC components threatens the results obtained and the models developed linking IC and innovation. It is understandable that authors select the definitions and scales that best represent the phenomena they wish to measure; however, this flexibility may have resulted in the disorganised development of multiple understandings of IC components and diverse manners of operationalising them.

Innovation

The extant literature recognises the diversity surrounding innovation. Sáenz and Aramburu (2011, p. 89) argue that "A unique and commonly accepted definition of innovation does not exist, but most of the existing ones agree that innovation implies conceiving and implementing something new". Lee and Tsai (2005, p. 328) affirm that "There are plenty of studies related to innovation. However, researchers defined it from very various perspectives". Crossan and Apaydin (2010) claim that "Innovation is a broad term with multiple meanings; it draws on theories from a variety of disciplines and has been studied using a wide range of research methodologies" (p. 1165). All this diversity makes it necessary to analyse the various ways of conceiving innovation in the set of studies analysing innovation's IC antecedents.

In order to classify the types of innovation present in each study, an exploratory approach has been followed. After all of the articles have been scanned, their innovation types or dimensions were identified, and the studies were codified accordingly. The results confirm the great diversity related to the term "innovation", since innovation has been measured according to the results of innovation (26 studies), the process of innovation (five studies), the degree of radicality (six studies) and the innovative character, or innovativeness (three studies). In the following, each of these groups will be briefly explained.

The results group (26 studies) measures innovation in terms of the consequences of the act of innovating. In other words, results-oriented research focusses on the effect of the innovation process, such as new products, services, processes or managerial practices. A distinction has been made between output (six articles) and outcome (eight articles). While output measures innovation in terms of production (e.g. amount of new products introduced Wu *et al.*, 2007), outcome concentrates on the results of those innovations (e.g. the market, financial, customer and product performance of the new product (Hsu and Fang, 2009). Studies combining output and outcome measures are also popular (11 articles), while the combination of output and radical innovation only accounts for one study.

The process of innovating concentrates on the ways to innovate (one study) and the capabilities of achieving the aforementioned results (four studies). The ability to adjust processes to accommodate changes in production (Menor *et al.*, 2007), the capacity to sense and shape opportunities and threats (Aramburu and Sáenz, 2011) and the ability to seize opportunities (Aramburu *et al.*, 2015), among others, will influence the future results of innovation activities.

The degree of radicality (six studies) is related to the degree of change of the developed innovation. As explained in the OECD (2005), following Schumpeter's school of thought, radical innovations "create major disruptive changes" while incremental innovations "continuously advance the process of change" (p. 29). Delgado-Verde *et al.* (2015) regard

incremental changes as insufficient to guarantee a firm's survival; thus, they focus their attention on radical innovations. Others prefer to consider both incremental and radical innovations simultaneously in order to establish comparisons and analyse their differences (Ramezan, 2012; Dumay *et al.*, 2013; Wang and Chen, 2013).

Innovativeness (three studies) focusses on an organisation's desire and intention to innovate. It measures the priority given to innovation and the intention to frequently try new ideas and improve old products, among others (Hsu and Sabherwal, 2011; Kipkirong and Kiptanui, 2015).

Moreover, studies on the results and degrees of radicality were also classified according to the nature of the creation (e.g. product, service, process, technology or managerial practice) (Figure 4). Of all the studies, 42.5 per cent (17 out of 40) have concentrated exclusively on product innovation, and, in fact, the creation of new products is present in almost all of the groups identified (67.5 per cent, 27 out of 40 articles).

Despite the diverse ways of understanding innovation, there is a clear inclination towards measuring innovation according to the results of the process, on one hand, and product innovation, on the other. This has caused the detailed development of measures related to results and product innovation, but much remains to be understood regarding the measurement of process innovation and innovativeness, among others. In addition, the measures adopted do not combine various elements from the four groups identified. Instead, they are focussed on either the results of the innovation activity, the innovation process, the degree of radicality or the innovativeness of the company. In order to represent the "larger picture" of innovation, various dimensions of innovation should be integrated (Crossan and Apaydin, 2010, p. 1166). Hence, the current ways of measuring innovation provide partial understandings of the complete phenomena of innovation.

Research questions and hypotheses

On the basis of the analysis made by Massaro *et al.* (2016) concerning the use of research questions and hypotheses in the field of knowledge management in SMEs, this study has checked whether research questions and hypotheses are commonly defined within this field. For the purposes of this study, only those articles that explicitly state either the research question or the hypothesis or both were not classified into the "neither research

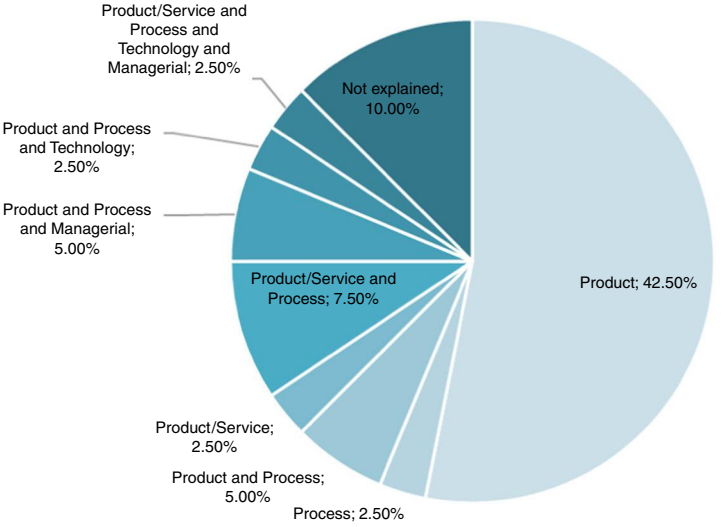

Figure 4.
Nature of the creation

question nor hypothesis" group. The results show a high level of maturity in the field, since only 7.5 per cent of the articles do not include research questions or hypotheses. Of the remainder, 2.5 per cent of them define research questions only, 75 per cent propose hypotheses only and 15 per cent consider both research questions and hypotheses.

Findings and areas of implications

Research findings are clearly identified in all the analysed articles. However, a deeper analysis reveals the existence of conflicting findings, some of which are shown in Table VI. There is no unique way of enhancing innovation by means of IC components, since the models provided by some articles differ from those verified by others. For example, while HC is a mediator in some articles, its effect is mediated in others. Similarly, structural and RC also jump among positions within the analysed models, and each one of the three IC components are the most, the second-most or the least important for innovation, depending on the article.

According to previous categories analysed, the location of the firm, the industry to which it belongs (in terms of manufacturing vs services), the technology level and the size (in terms of SMEs vs large companies) all produce differences in both IC and innovation (Nooteboom, 1994; Hipp and Grupp, 2005; Cohen and Kaimenakis, 2007; De Carolis, 2010; Hofstede *et al.*, 2010; Kianto *et al.*, 2010; Schilling, 2011). Therefore, it is expected that these different models respond to a varying range of possibilities in the aforementioned categories. For example, high-tech companies manage complex knowledge; thus, it is expected that HC plays a prominent role in these firms. This is the case in Costa and Ramos' (2015) research, but it applies differently to the work of Hsu and Fang (2009). Hence, even though the aforementioned variables should be somehow related to the different models, there is no clear explanation that solves every conflict.

The research implications are explained in 92.5 per cent of the studies (37 articles), which is consistent with the finding that most of the analysed articles were authored by academics. These implications for further research can be classified into six groups, as follows:

- use secondary objective data for the measurement of innovation (Hsu and Fang, 2009; Cabello-Medina *et al.*, 2011; Chen *et al.*, 2014);

Table VI.
Conflicting findings

1. Cabello-Medina *et al.* (2011), Carmona-Lavado *et al.* (2013)	Human capital exerts a direct influence on innovation and mediates the impact of social and/or organisational capital on innovation
Chen *et al.* (2014), Costa *et al.* (2014)	The impact of human capital on innovation is mediated by customer or structural capital
2. Carmona-Lavado *et al.* (2010), Chen *et al.* (2014), Delgado-Verde, Amores-Salvadó, Martín de Castro and Navas-López (2014)	Social or customer capital mediates the influence of organisational capital on innovation
Costa *et al.* (2014), Elsetouhi *et al.* (2015)	Structural or organisational capital mediates the impact of relational or social capital on innovation
3. Chen *et al.* (2014)	Customer capital mediates the influence of organisational capital on innovation
Elsetouhi *et al.* (2015)	Organisational capital mediates the impact of customer capital on innovation
4. Chen *et al.* (2006)	Relational capital is the most relevant component, followed by human and finally structural capital
Costa and Ramos (2015)	Human capital is the most relevant component, followed by relational and finally structural capital
Hsu and Fang (2009)	Relational capital is the most relevant component, followed by structural and finally human capital
Zhang and Lv (2015)	External social capital is the most relevant component

- improve the measures for both IC and innovation (Chien, 2010; Leitner, 2011; Chen *et al.*, 2015);
- improve the models developed by including other variables and/or relationships (Menor *et al.*, 2007; Wu *et al.*, 2008; Carmona-Lavado *et al.*, 2010; Lee *et al.*, 2011);
- extend or replicate the model in other sectors and countries (Aramburu and Sáenz, 2011; Delgado-Verde, Navas-López, Cruz-González and Amores-Salvadó, 2011; Carmona-Lavado *et al.*, 2013);
- consider the size of the company and/or compare SMEs and large companies (Hsu and Sabherwal, 2011; Leitner, 2011; Costa *et al.*, 2014); and
- develop a longitudinal study in order to check the relationships over time (Chen *et al.*, 2006; Wu *et al.*, 2008; Wang and Chen, 2013).

With respect to practical implications, 80 per cent of the studies (32 articles) provide implications for business practice; however, the participation of practitioners in the set of studies analysed is almost non-existent. In other words, the existing practical implications have been developed by academics. This could produce a disconnection between the developed practical implications and the real problems that exist in the business world.

In fact, a deeper analysis of the practical implications reveals that many are fairly superficial. Some researchers simply rewrite the results of the study (Chien and Chao, 2011; Wang and Chen, 2013), while others merely comment on what managers should work on or strengthen (Delgado-Verde, Martín de Castro, Navas-López and Amores-Salvadó, 2014; Elsetouhi *et al.*, 2015). They do not provide guidelines on how managers can strengthen IC components and, therefore, seem to be largely disconnected from real business practice. Paradoxically, therefore, the IC research trend, which emerged from business practice (Petty and Guthrie, 2000), is so far unable to offer practitioners useful insight or guidelines for how to apply the models developed.

Finally, another disconnection exists between the worlds of research and policy. Only 5 per cent of the studies (two articles) offer implications for policy-makers; the remaining 95 per cent simply do not mention them. This disconnection is surprising, considering that companies are economic agents that operate in a larger environment in which governments play a key role. According to the OECD's (2015) innovation strategy, the creation of an economic environment suitable for innovating, taking into consideration the "realities of innovation as it occurs today" (p. 6) is one of the main tasks of governments. Hence, a large amount of valuable knowledge about how to enhance innovation in organisations has not yet been exploited by policy-makers. Without such a connection, it will be difficult for policies designed to create innovative economic environments to address the needs of companies operating in those environments.

Subramaniam and Youndt (2005)

Since this seminal article has been taken as a reference point, it is worthwhile to examine how frequently it is referenced by the selected studies. As expected, the great majority of articles (77.5 per cent or 31 articles) cite this seminal paper in their reference lists. It seems that this seminal paper has influenced the evolution of the research on the IC-innovation linkage by means of direct quotes (Menor *et al.*, 2007; Aramburu and Sáenz, 2011; Wang and Chen, 2013; Aramburu *et al.*, 2015), definitions and interpretations of IC and its components (Cabello-Medina *et al.*, 2011; Chen *et al.*, 2014; Delgado-Verde, Martín de Castro, Navas-López and Amores-Salvadó, 2014; Costa and Ramos, 2015) and relationships among IC components when boosting innovation (Carmona-Lavado *et al.*, 2010; Delgado-Verde, Navas-López, Cruz-González and Amores-Salvadó, 2011; Carmona-Lavado *et al.*, 2013), among others.

Discussion

The following discussion answers the third research question:

RQ3. What is the future for the IC-innovation relationship literature?

Lack of an agreed model(s) for how IC influences innovation

As the conflicting findings highlight, there is no consensus on how IC influences innovation. On the basis that IC is one of the main antecedents of innovation (Subramaniam and Youndt, 2005), researchers have developed different models representing how this relationship works in different settings. However, this has led to a proliferation of models that are, in some cases, contradictory.

As has been explained in this study, the location of the firm, the industry to which it belongs, its technology level and its size all influence both IC and innovation (Nooteboom, 1994; Hipp and Grupp, 2005; Cohen and Kaimenakis, 2007; De Carolis, 2010; Hofstede *et al.*, 2010; Kianto *et al.*, 2010; Schilling, 2011). Indeed, research implications collected from various studies agree on the need for comparisons among industries, countries and firms of different sizes. Nevertheless, studies in general have paid little attention to these variables. Hence, there is a risk of developing models that stem from the general hypothesis that IC influences innovation, but fail to take into account the more particular issues, such as firms' locations, sizes, industries and technology levels, which are likely to produce significant contingencies in the IC-innovation relationship.

Traditional IC components and combinations

This study has demonstrated that researchers in this domain prefer the traditional three-dimensional IC framework and terminology. The seminal paper published by Subramaniam and Youndt (2005) has been repeatedly used as a reference for defining IC and explaining its components. However, this does not mean that the traditional framework, which ultimately dates back to the end of the 1990s – to the pioneering works of Edvinsson and Malone (1997) and Bontis (1998) – is the most suitable for representing the intangibles of a company. Key trends reported by the OECD's (2015) innovation strategy (i.e. "the spread of global value chains, the increasing importance and mainstreaming of KBC, and rapid technological progress" (p. 2) show the continuous evolution of business environments. Social and technological advances are likely to have altered the way in which companies produce goods and services, the employee profiles needed in companies, and the kind of work offered by firms, among others. Thus, there is a need for further research on the intangibles operating in current companies.

Even though all the studies analysed build on the traditional IC components, the more specific way in which those IC components have been operationalised differs a great deal. In fact, improving existing ways of conceptualising IC components is one of the implications for research collected from the analysed set of studies. The current abundance of definitions and ways of operationalising the constructs is not used by researchers for adapting to the differences emerging with respect to company industry (Hipp and Grupp, 2005; Kianto *et al.*, 2010), technology level (De Carolis, 2010; Schilling, 2011) and size (Nooteboom, 1994; Cohen and Kaimenakis, 2007). Instead, there has been a disorganised development of understandings of IC components that do not enhance the differences embedded in companies of various industries, technology levels and sizes. Consequently, further research could benefit from the development of diverse IC frameworks that respect and adapt to the aforementioned differences.

Complete view of the innovation process

Though there is a great diversity surrounding innovation, the studies analysed offer only partial understandings of the issue. As Crossan and Apaydin (2010) conclude, it is necessary to integrate various dimensions of innovation so as to get a complete understanding of it. The current

simplistic way of conceptualising innovation in IC studies poses the risk of developing models for enhancing a minor proportion of what innovation really represents in a company.

The relevance of innovation in the current business environment requires studies to adopt a complete view of the entire phenomenon of innovation. Important areas for study include not only the results of innovation, but also the processes for achieving these results, the capability to succeed in innovation activities, and the intention and desire to innovate, among others.

Disconnection between research and business practice

The lack of practitioners taking part in the studies analysed, as well as the superficial implications for practice found in these articles lead to the conclusion that there is a worrying disconnection between research and business practice as far as the IC-innovation relationship is concerned. It is remarkable that such a disconnection occurs in an area that emerged from the needs and desires of practitioners (Petty and Guthrie, 2000).

In addition, the popularity of quantitative methods over qualitative ones is not helpful for bridging the gap between researchers and practitioners. Since quantitative methods try to test theories and develop laws (Bryman and Bell, 2011), they do not allow a deeper understanding of the specific characteristics of IC components working for enhancing innovation in a company. These quantitative methods reduce the reality to objects to be numerically measured in an already developed way; thus other interpretations and understandings of the reality that business practitioners may offer are not considered.

Disconnection between research and policy-makers

Since implications for policy are almost non-existent in the analysed studies, there is a clear disconnection between academics and policy-makers. Governments are in charge of the development of economic environments that facilitate company innovation (OECD, 2015); thus, certain degree of clarification about how IC enhances innovation at the company level should be highly desirable for policy-makers.

Conclusions

This paper seeks to offer a comprehensive review of the articles addressing the IC-innovation relationship in order to present the main insights and critique the evolution of the research field, as well as to propose future research lines. In general, the linkage between IC and innovation has been explored in great detail, and valuable knowledge has been generated. This study has shown that there is no consensus about the enhancement of innovation by the strengthening IC components and, most probably, this lack of consensus emerges from differences regarding firm's location, technology level, industry and size. In addition, research world in this domain is isolated from both practice and policy-making, and the ways of conceptualising both IC and innovation need further refinement in order to adjust to the current business environment.

Despite the described findings, this research has some limitations that should be carefully considered. First, though a rigorous methodology has been followed, the results could be influenced by the fact that the analysis was conducted by only one person. A study developed by a diverse team comprising both academics and practitioners could delve deeper into the insights raised in this study and interpret these insights from different perspectives. Second, the study is reduced to the analysis of journal articles published from 2006 to 2015. Though the criteria for selecting research works has been coherently justified, relevant books and works prior to 2006 have been excluded from this study.

In addition, the paper presents remarkable implications for researchers and practitioners. Academics can get pertinent insights on the evolution of the research concerning the relationship between IC and innovation, which could be helpful for guiding their future works on this domain. The study offers valuable guidelines on different IC components,

ways of understanding and conceptualising innovation, and variables that affect the IC-innovation linkage, among others. Managers may use this knowledge as a general framework and a starting point for strengthening IC and innovation in their organisations.

Regarding potential areas for future research, it could be highly beneficial to deepen into the specificities of the IC-innovation linkage contingent upon firms' locations, industries, technology levels and size. In relation to this, it is recommendable to develop diverse IC frameworks for understanding and conceptualising IC that respect the aforementioned differences and support research studies' attempts to more deeply explore the specificities of the IC-innovation linkage.

As for the measurements of both IC and innovation, more research is needed to analyse whether there are intangible assets under-represented or not represented by the traditional IC components, on one hand, and the adoption of multidimensional measures of innovation that combine elements of different natures with objective (i.e. secondary) data, on the other.

Additionally, future studies should include implications for policy-makers, and greater practitioner participation so as to include the real viewpoint of business people. To increase and improve implications for business practitioners, two approaches are proposed: include practitioners as co-authors of the articles analysing the IC-innovation linkage and apply qualitative research methods that bring together academics and practitioners. This second approach will also be beneficial for deepening our interpretive understanding of the reality of the IC-innovation linkage and gaining new insights that differ from those provided by the positivistic approach.

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Appendix

Reference	Publication	EBSCO	Scopus	WOS
Aramburu and Sáenz (2011)	*Journal of Management & Organization*		X	X
Aramburu *et al.* (2015)	*Cuadernos de Gestión*	X	X	
Cabello-Medina *et al.* (2011)	*The International Journal of Human Resource Management*	X	X	X
Carmona-Lavado *et al.* (2013)	*Industry and Innovation*	X	X	X
Carmona-Lavado *et al.* (2010)	*Industrial Marketing Management*	X	X	X
Castro *et al.* (2013)	*Knowledge Management Research & Practice*		X	X
Chahal and Bakshi (2015)	*International Journal of Bank Marketing*	X	X	
Chen *et al.* (2014)	*Journal of Engineering and Technology Management*		X	X
Chen *et al.* (2015)	*International Journal of Technology Management*	X	X	X
Chen *et al.* (2006)	*Total Quality Management and Business Excellence*	X	X	X
Chien (2010)	*Asia Pacific Management Review*		X	
Chien and Chao (2011)	*The Service Industries Journal*	X	X	X
Costa *et al.* (2014)	*Knowledge Management Research & Practice*			X
Costa and Ramos' (2015)	*International Journal of Business Science and Applied Management*		X	
Delgado-Verde, Amores-Salvadó, Martín-De Castro and Navas-López (2014)	*Knowledge Management Research & Practice*		X	X
Delgado-Verde, Castro and Navas-López (2011)	*Journal of Intellectual Capital*	X	X	
Delgado-Verde *et al.* (2015)	*International Journal of Technology Management*	X	X	X
Delgado-Verde, Martín de Castro, Navas-López and Amores-Salvadó (2014)	*Knowledge Management Research & Practice*		X	X
Delgado-Verde, Navas-López, Cruz-González and Amores-Salvadó (2011)	*Journal of Knowledge Management*		X	X
Dumay *et al.* (2013)	*Journal of Intellectual Capital*	X	X	
Elsetouhi *et al.* (2015)	*International Journal of Innovation Management*	X	X	
Fan and Lee (2012)	*Expert Systems with Applications*	X		
Han and Li (2015)	*Management Decision*	X	X	X
Hsu and Fang (2009)	*Technological Forecasting and Social Change*		X	
Hsu and Sabherwal (2011)	*IEEE Transactions on Engineering Management*	X		X
Lee, Swink and Pandejpong (2011)	*Production and Operations Management*	X		
Kipkirong and Kiptanui (2015)	*Journal of African Business*	X		
Leitner (2011)	*International Journal of Technology Management*	X	X	X
Martín de Castro *et al.* (2013)	*Technological Forecasting and Social Change*		X	X
Menor *et al.* (2007)	*Manufacturing & Service Operations Management*	X	X	
Ramezan (2012)	*Education, Business and Society: Contemporary Middle Eastern Issues*		X	
Santos-Rodrigues, Fernández-Jardón and Dorrego (2015)	*International Journal of Knowledge-Based Development*		X	
Sivalogathasan and Wu (2015)	*International Journal of Innovation Science*		X	
Subramanian (2012)	*IEEE Transactions on Engineering Management*	X		
Ugalde-Binda *et al.* (2014)	*Innovar*		X	
Wang and Chen (2013)	*International Journal of Manpower*	X	X	X
Wu *et al.* (2008)	*R&D Management*	X	X	X
Wu *et al.* (2007)	*International Journal of Technology Management*	X	X	X
Zerenler *et al.* (2008)	*Journal of Technology Management & Innovation*	X		
Zhang and Lv (2015)	*International Journal of Innovation Science*		X	

Note: WOS stands for "Web of Science"

Table AI. Articles analysed

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Publication 2

Buenechea-Elberdin, M., Kianto, A. and Sáenz, J.

Intellectual capital drivers of product and managerial innovation in high-tech and low-tech firms

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Intellectual capital drivers of product and managerial innovation in high-tech and low-tech firms

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There is widespread understanding that intellectual capital (IC), consisting of the valuable knowledge resources of an organization, is a key enabler of innovation activities; however, little is known about the more specific contingencies impacting the relationship between IC and innovation. Thus, this article examines firm technology level and innovation type as contingency variables. It was argued that because high-tech and low-tech firms differ in terms of several knowledge characteristics (complexity, tacitness and pace of renovation), it is likely that their innovation performance is supported by different combinations of IC components. Furthermore, differences between product/service and managerial innovation could also lead to changes in the degree of relevance of various IC components. To test these contingency hypotheses, a survey dataset collected from 180 Spanish companies is analysed using structural equation modelling. The results demonstrate that both firm's technology level and type of innovation affect how IC influences innovation performance. The findings contribute to a knowledge-based perspective on innovation and pave the way for a more context-sensitive and contingency-mindful approach to understanding innovation and knowledge-based value creation.

1. Introduction

In the current globalized, digitalized and fast-paced economy, the role of knowledge as a valuable organizational resource has gained increasing attention (Drucker, 1993; Nonaka and Takeuchi, 1995; Grant, 2002). The knowledge-based view of the firm (e.g. Kogut and Zander, 1992; Grant, 1996; Spender, 1996)

argues that sustained company viability and competitiveness are based on the intangible resources and capabilities governed by firms. As knowledge has become a strategic resource, it is increasingly referred to as intellectual capital (Edvinsson and Malone, 1997; Bontis, 1998; Tseng and James Goo, 2005). From the knowledge-based perspective, innovation management is essentially a question of exploiting the intellectual capital (IC) of a firm (Subramaniam and Youndt, 2005). Indeed, IC is widely seen to function as a crucial enabler of innovation through its main components (human capital, structural capital and relational capital), which represent valuable knowledge embedded in an organization's people, structures and relationships (Cabello-Medina et al., 2011; Delgado-Verde et al., 2014; Aramburu et al., 2015).

Innovations come in many shapes and sizes, from new products and services to novel management and marketing methods, production processes and strategic outlooks (e.g. OECD, 2005; Bessant and Tidd, 2007). It is well-known that different innovation types benefit from various antecedents; for example, product innovations can be boosted by a firm's intensity of physical capital and the extent to which the firm develops various innovation projects (Damanpour and Aravind, 2006), whereas management innovations thrive in organizations where policies and procedures are formalized (Damanpour and Aravind, 2012). Therefore, it seems likely that the knowledge-based antecedents of innovation would also differ as a function of innovation type. However, while differences between various innovation types have been demonstrated clearly in the more general innovation management literature, there seems to be a lack of understanding concerning what knowledge assets are most important for different types of innovation. Consequently, managers have little guidance regarding which knowledge resources to primarily invest in if they are to support particular types of value-creating novelties in their organizations.

Compared with product and service innovation, innovations in management practices are more internal to individual firms (Damanpour and Aravind, 2012); hence, they depend more on the idiosyncrasy of each corporation. This suggests that there may also be differences in the degree of relevance of each IC component when it comes to enhancing product/service innovation versus managerial innovation. However, the existing literature analysing the influence of IC on innovation has overlooked comparisons between different innovation types. With the exception of a few studies comparing the influence of various IC components in incremental versus radical innovations (Subramaniam and Youndt, 2005; Wang and Chen, 2013), and one study comparing the IC antecedents of product, process and managerial innovation (Elsetouhi et al., 2015), there is little research into how the role of IC differs depending on the type of innovation considered. This article addresses this gap by analysing the influence of various IC components on both product/service and managerial innovations.

Moreover, just as innovation types vary, the firms producing them differ. Understanding firm characteristics as contingencies in the IC–innovation linkage is important, as various types of firms may benefit from different intangibles in their innovation processes. A characteristic likely to be especially influential in determining what intangibles drive innovation is technology level; high- and low-tech companies differ substantially in the type of knowledge they utilise. However, no previous studies have looked at technology level as a contingency variable impacting the role of IC in innovation. In fact, the majority of existing studies on the IC–innovation linkage have examined high-tech firms (e.g. Wu et al., 2007; Martín-de-Castro et al., 2013), while very few have addressed low-tech companies (e.g. Leitner, 2011) and none have compared the two. The lack of understanding about which intangibles matter most for innovation in different types of organizations hinders managers from making informed decisions concerning which IC components they should be investing in and developing to best fit the needs of their firm. Therefore, this study also addresses the question of how the relationships between IC and innovation might vary in different kinds of firms, specifically, by differentiating between high- and low-technology companies.

To empirically examine these issues, we analyse data collected via a structured questionnaire from 180 Spanish firms. The findings demonstrate that product/service and managerial innovations depend on different IC components and that these patterns vary between high- and low-tech firms. Thus, the article contributes to a knowledge-based perspective on innovation and its management.

2. Theoretical background and hypotheses

2.1. Intellectual capital

The IC perspective of management evolved in the early 1980s from the needs of business practitioners to better understand the basis of organizational performance and it was consolidated throughout the 1990s as a legitimate and popular academic approach (Bontis, 1998; Petty and Guthrie, 2000; Dumay,

2014). The IC perspective is ultimately grounded in knowledge-based strategy theory, which traces the sources of competitiveness to intangible resources and capabilities (Kogut and Zander, 1992; Grant, 1996; Spender, 1996). IC research evolved in three stages: the first stage (from early 1980 to the mid-1990s) focused on 'consciousness raising and creating mass awareness of the relevance of intellectual capital' (Petty and Guthrie, 2000, p. 162); the second stage (from late 1990s to early 2000) aimed to measure and manage IC (Petty and Guthrie, 2000), as well as analysing the influence of IC on financial outcomes (Dumay and Garanina, 2013); finally, the third stage focuses on a bottom-up understanding of how IC works in practice (Dumay and Garanina, 2013).

Together with the evolution of IC research, its definition and components have also evolved. The countless definitions of IC published in books and journal articles can be classified into two groups: knowledge-based and holistic (Sáenz and Aramburu, 2011). The knowledge-based perspective conceives IC as the knowledge resources used by the firm to gain competitive advantages, whereas the holistic perspective understands IC as the sum of knowledge resources and other intangible assets the firm manages (Sáenz and Aramburu, 2011). This research adopts the knowledge capital perspective; thus, IC is defined as all valuable knowledge-related resources that an organisation controls or has access to and manages in order to gain sustainable competitive advantages.

Regardless of perspective, IC is split into different components. The seminal articles published by Bontis (1998) and Subramaniam and Youndt (2005) distinguished between human, structural and customer capital, and human, social and organisational capital, respectively. According to Reed et al. (2006), 'while the terms to label the various IC components may differ, conceptually IC consists of three basic components: human, organizational, and social capital, the last containing both external and internal dimensions' (p. 870). These three IC components (i.e. human, organisational/structural and social capital) are widely regarded as the traditional IC framework and is the one preferred by researchers. Consequently, this research applies the traditional IC framework and IC will thus be split into human, structural and relational capital. In the following, each IC component is described in more detail.

Human capital (HC) encompasses organizational members and their attributes, such as knowledge, skills, experience, attitudes and motivation (Edvinsson and Malone, 1997; Stewart, 1997; Bontis, 1998). HC is considered the cornerstone of IC, although it is not under complete management control: employees are the real owners of HC and companies can only rent employees' HC in exchange for a salary (Roos et al., 1998).

Structural capital (SC) consists of the knowledge accumulated and distributed through firms' structures and processes, such as information systems, cultural traits and management systems (Edvinsson and Malone, 1997; Stewart, 1997; Bontis, 1998). SC includes both infrastructural assets that form the context for activities and codified knowledge such as documents, databases and intellectual property rights.

Internal relational capital (IRC) is the knowledge embedded in and available for the firm through the webs of relationships among its members (Nahapiet and Ghoshal, 1998; Kianto and Waajakoski, 2010).

External relational capital (ERC) includes knowledge and resources related to the firm's external relationships, such as connections with customers, suppliers, partners and the local community (Edvinsson and Malone, 1997; Bontis, 1998).

2.2. Intellectual capital and innovation

Innovation is substantially related to knowledge. It implies the creation of new knowledge, both as an input (new ideas, concepts, prototypes) as well as an outcome (the produced novelty). Thus, a firm's knowledge resources are key enablers of innovation (e.g. Nonaka and Takeuchi, 1995; Subramaniam and Youndt, 2005). Previous studies have examined the role of IC in the production of innovations (e.g. Subramaniam and Youndt, 2005; Menor et al., 2007; Wu et al., 2007; Wu et al., 2008; Leitner, 2011; Carmona-Lavado et al., 2013; Martín-de-Castro et al., 2013), demonstrating that IC is relevant to innovation.

A detailed examination of the impact of IC on innovation makes obvious that employee-related resources enhance innovation. As Carmona-Lavado et al. (2013, p. 149) put it, 'previous research has already suggested that intellect, which clearly resides inside the firm's human brains, is an unquestionable facilitator of innovation'. Unique employees who own rare knowledge, which totally differs from the knowledge owned by competitors, play a key role in the development of innovations (Cabello-Medina et al., 2011). Hence, the following hypothesis is suggested:

H1: *Human capital positively affects: (a) Product/service innovation in both (i) high-tech and (ii) low-tech firms; and (b) Managerial innovation in both (i) high-tech and (ii) low-tech firms.*

In addition, structural capital contributes significantly to innovation by providing knowledge codified and stored in databases, written procedures and information systems, as well as state-of-the-art processes and technology for integrating different work processes

(Menor et al., 2007; Wu et al., 2007; Wang and Chen, 2013). Therefore, the next hypothesis is suggested:

H2: *Structural capital positively affects: (a) Product/service innovation in both (i) high-tech and (ii) low-tech firms; and (b) Managerial innovation in both (i) high-tech and (ii) low-tech firms.*

Subramaniam and Youndt (2005) emphasized the collaborative nature of the innovation process (p. 459); thus, the internal relationships among managers and employees that facilitate knowledge sharing (i.e. internal relational capital) are crucial in the development of innovations (Nonaka and Takeuchi, 1995; Carmona-Lavado et al., 2010). Consequently:

H3: *Internal relational capital positively affects: (a) Product/service innovation in both (i) high-tech and (ii) low-tech firms; and (b) Managerial innovation in both (i) high-tech and (ii) low-tech firms.*

Moreover, all knowledge important for innovation cannot possibly reside within a single particular firm. In other words, the creation of new knowledge and the development of new combinations of existing knowledge (i.e. innovation) (Eisenhardt and Martin, 2000) may require external sources of knowledge that provide indispensable information about customers, suppliers and other strategic partners (Wu et al., 2007; Hsu and Fang, 2009). Thus, the following hypothesis is posed:

H4: *External relational capital positively affects: (a) Product/service innovation in both (i) high-tech and (ii) low-tech firms; and (b) Managerial innovation in both (i) high-tech and (ii) low-tech firms.*

2.3. The role of IC in innovation in high-tech and low-tech firms

We claim along with Reed et al. (2006) that context matters for how knowledge resources are used in value creation. One important contingency factor in the IC–innovation relationship is the technology level of a given firm. According to De Carolis (2010), high-technology industries are characterised by rapid advances in science and technology, requiring firms to move very quickly to sustain a technological edge and bring new products to the market. Moreover, high-tech usually involves more complex knowledge (i.e. knowledge with many underlying components and/or many interdependencies between those components) and a greater degree of tacitness (Schilling, 2011) than low-tech. Consequently, knowledge residing in firms operating in high- and low-technology industries will differ significantly, which is likely to generate remarkable differences in the IC–innovation linkage.

A deeper analysis of the role of a firm's technology level in the IC–innovation relationship shows that the superior knowledge complexity (Schilling, 2011) and speed of knowledge renewal (De Carolis, 2010) characterising high-tech industries makes necessary employees who are highly knowledgeable and skilful. This is consistent with Delgado-Verde et al. (2015), who demonstrated that employees' education, training, experience and abilities significantly promote innovation in high-tech firms. Conversely, in low-tech companies the competency demands of innovation are likely less sophisticated. Therefore,

H5: *The influence of human capital on (a) product/service and (b) managerial innovation performance is significantly larger in high-tech firms than in low-tech firms.*

As high-tech companies deal largely with tacit knowledge (Schilling, 2011), which is difficult to codify and transfer (Nonaka and Takeuchi, 1995), their innovation efforts will benefit to a lesser extent from knowledge stored in manuals, databases and written procedures. On the contrary, as easy-to-codify knowledge is more frequent in low-tech firms, these companies could benefit to a larger extent from knowledge stored in databases and information systems. Hence, the following hypothesis is formulated:

H6: *The influence of structural capital on (a) product/service and (b) managerial innovation performance is significantly lower in high-tech firms than in low-tech firms.*

In addition, the greater degree of tacitness of knowledge managed in high-tech companies (Schilling, 2011) makes internal relationships among employees even more relevant. As Nonaka and Takeuchi (1995) point out, tacit knowledge can only be transferred by means of social interaction. Along these lines, Delgado-Verde et al. (2011) demonstrated the positive influence of such interaction among employees on innovation in high-tech firms. In contrast, social interaction in low-tech companies becomes less relevant as explicit knowledge (i.e. knowledge that can be easily codified and transferred) is more present. Thus:

H7: *The influence of internal relational capital on (a) product/service and (b) managerial innovation performance is significantly larger in high-tech firms than in low-tech firms.*

Relying on relationships with customers, suppliers and key strategic partners is equally necessary for both high- and low-tech companies. Low-tech

companies often lack internal innovation capabilities, which makes knowledge from external sources extremely relevant. In high-tech firms, however, although well-established internal innovation capabilities may exist, superior knowledge complexity (Schilling, 2011) makes it difficult for one firm to have all the knowledge needed to develop a particular innovation. Hence, external cooperation becomes critical. Moreover, high-tech products are usually 'competence destroying' as they require customers to acquire new knowledge to use them. Consequently, intense relationships with customers are highly beneficial for innovation (Meeus and Edquist, 2006, p. 29). As a result, the following hypothesis is suggested:

H8: *The influence of external relational capital on (a) product/service and (b) managerial innovation performance is equally relevant in both high- and low-tech firms.*

2.4. IC and product/service versus managerial innovations

According to the OECD (2005), innovation can be divided into novelties introduced in products and services, processes, marketing practices and organizational advancements. Product innovation, which includes services, refers to 'the introduction of a good or service that is new or significantly improved with respect to its characteristics or intended uses' (OECD, 2005, p. 48). Organizational innovation 'is the implementation of a new organisational method in the firm's business practices, workplace organisation or external relations' (OECD, 2005, p. 51). According to Damanpour and Aravind (2012) the terms organizational and administrative innovations have lost relevance in favour of management innovation. Thus, this study uses the term managerial innovation.

The relevance of distinguishing between innovation types was already highlighted in the seminal article published by Damanpour in 1987, which argued that the inability to develop a reliable theory on innovation adoption was partly due to the failure to distinguish between various types of innovation when doing research, which provokes finding instability (p. 675).

A thorough analysis into the differences embedded into various innovation types shows that human capital, unlike other IC components, is equally relevant for both product/service and managerial innovation. Because knowledgeable and skilful employees are a firm's most important knowledge asset (Wright et al., 1994) and innovation is intrinsically a human activity, both product/service and managerial innovation will be greatly dependent on workers' capabilities. Thus,

H9: *Human capital is equally relevant for both product/service and managerial innovation performance in both (a) high-tech and (b) low-tech firms.*

Concerning structural capital, managerial innovations imply changes in the structure of the firm that profoundly alter the inner workings of the company. 'Whereas the introduction of a technological innovation does not require reassignments of corporate functions and responsibilities … the introduction of a major administrative innovation typically requires major reassignments of tasks and responsibilities in a fashion which needs not leave all personnel unambiguously better off' (Teece, 1980, p. 465). Managerial innovations imply new approaches 'for performing the work of management and new processes that produce changes in the organization's strategy, structure, administrative procedures, and systems' (Damanpour and Aravind, 2012, pp. 429–432). Hence, these changes benefit from knowledge codification. Consequently:

H10: *Structural capital is more relevant for managerial innovation performance than for product/service innovation performance in both (a) high-tech and (b) low-tech firms.*

In contrast to product/service innovations, which are introduced to satisfy client needs (Damanpour and Aravind, 2012), managerial innovations are characterised by an internal-to-the-firm approach as they are introduced to enhance 'the efficiency and effectiveness of firms' management processes and administrative systems' (Damanpour and Aravind, 2012, p. 428). Product/service innovations need external verification while managerial innovations should meet firm's internal needs. Thus, the internal exchange of knowledge among employees (i.e. internal relational capital) will greatly enhance managerial innovations, while new knowledge coming from customers, suppliers and strategic partners (i.e. external relational capital) will primarily promote product/service innovations. Consequently, the following hypotheses are proposed:

H11: *Internal relational capital is more relevant for managerial innovation performance than for product/service innovation performance in both (a) high-tech and (b) low-tech firms.*

H12: *External relational capital is more relevant for product/service innovation performance than for managerial innovation performance in both (a) high- tech and (b) low-tech firms.*

2.5. Control variables

This study also includes size and industry in the model as control variables. Small firms evidence

few hierarchical levels, simple procedures and short communication lines, which makes them flexible and agile (Nooteboom, 1994). They have fewer resources than big corporations (Nooteboom, 1994), but the increasing relevance of cooperation among firms helps to overcome this shortfall. Therefore, we suggest that size will exert a negative effect on innovation. Regarding industry, it is widely agreed that innovation propensity could change from one industry to another (Lee, 2005; Jiang et al., 2012). Thus, manufacturing and service firms were distinguished.

3. Research methods

3.1. Sample and data collection

The population of this study comprises Spanish companies with 100 employees or more. We used the SABI database (Sistema de Análisis de Balances Ibéricos; System of Iberian Balance Sheet Analysis) to identify firms; this database contains the registered annual accounts of around 2,500,000 Spanish and Portuguese companies. Initially, 1,289 firms met the established criteria and out of these, 700 were contacted by phone during the data collection period, which extended from October 2013 to February 2015 and was executed by the lead author. An attempt was made to balance manufacturing versus service companies and high-tech versus low-tech firms. Confidentiality was guaranteed to all participants in the research.

Firms were classified as high- or low-tech based on the technology-intensity classification of industries suggested by the OECD (Organisation for Economic Cooperation and Development) and EUROSTAT. Industries in higher categories (i.e. high or medium-high technology – in our study, high-tech) have a higher R and D intensity, whereas industries in lower categories (medium-low or low technology – in our study, low-tech) have a lower R and D intensity (OECD, 2011).

In total, 180 companies participated in the project (response rate: 25.71%) by answering a structured questionnaire. Of these, 86 (47.78%) were medium-high or high technology firms (i.e. high-techs), and 94 were medium-low or low technology companies (i.e. low-techs). Table 1 provides further details about the sectoral composition of the sample within each technology level.

Regarding profiles of respondents, 89.44% of participants held a responsible position in their firms, as managing directors (3.89%), human resource managers (67.22%) or heads of other departments (18.33%). The remaining 10.56% of participants were employees who did not occupy responsible positions.

Table 1. Sample composition

Industry	Frequency	Percentage
20 Manufacture of chemicals and chemical products	5	2.78%
21 Manufacture of basic pharmaceutical products and pharmaceutical preparations	3	1.67%
27 Manufacture of electrical equipment	3	1.67%
28 Manufacture of machinery and equipment n.e.c.	4	2.22%
29 Manufacture of motor vehicles, trailers and semi-trailers	14	7.78%
30 Manufacture of other transport equipment	2	1.11%
50 Motion picture, video and television programme production, sound recording and music publishing activities	3	1.67%
60 Programming and broadcasting activities	3	1.67%
61 Telecommunications	4	2.22%
62 Computer programming, consulting and related activities	35	19.44%
63 Information service activities	3	1.67%
72 Scientific research and development	7	3.89%
Medium-high and high technology subtotal	**86**	**47.78%**
10 Manufacture of food products	15	8.33%
11 Manufacture of beverages	5	2.78%
12 Manufacture of tobacco products	1	0.56%
13 Manufacture of textiles	1	0.56%
14 Manufacturing of wearing apparel	1	0.56%
15 Manufacture of leather and related products	2	1.11%
17 Manufacture of paper and paper products	1	0.56%
18 Printing and reproduction of recorded media	1	0.56%
22 Manufacture of rubber and plastic products	4	2.22%
23 Manufacture of other non-metallic mineral products	2	1.11%
24 Manufacture of basic metals	6	3.33%
25 Manufacture of fabricated metal products, except machinery and equipment	7	3.89%
31 Manufacture of furniture	1	0.56%
32 Other manufacturing	1	0.56%
33 Repair and installation of machinery and equipment	1	0.56%

Table 1. (*Continued*)

Industry	Frequency	Percentage
35 Electricity, gas, steam and air conditioning supply	1	0.56%
36 Water collection, treatment and supply	1	0.56%
41 Construction of buildings	1	0.56%
42 Civil engineering	2	1.11%
43 Specialised construction activities	1	0.56%
46 Wholesale trade, except of motor vehicles and motorcycles	3	1.67%
47 Retail trade, except of motor vehicles and motorcycles	1	0.56%
49 Land transport and transport via pipelines	8	4.44%
52 Warehousing and support activities for transportation	1	0.56%
55 Accommodation	3	1.67%
56 Food and beverage service activities	2	1.11%
58 Publishing activities	3	1.67%
70 Activities of head offices; management consultancy activities	2	1.11%
71 Architectural and engineering activities; technical testing and analysis	2	1.11%
74 Other professional, scientific and technical activities	3	1.67%
79 Travel agency, tour operator and other reservation service and related activities	1	0.56%
81 Services to buildings and landscape activities	2	1.11%
84 Public administration and defence; compulsory social security	1	0.56%
85 Education	1	0.56%
86 Human health activities	1	0.56%
87 Residential care activities	3	1.67%
88 Social work activities without accommodation	2	1.11%
Medium-low and low technology subtotal	**94**	**52.22%**
Total	**180**	**100.00%**

As data regarding all dependent and independent variables derive from the same self-reported survey, this could lead to the occurrence of what is known as 'common method bias' (Podsakoff et al., 2003). To determine the extent of method variance in the dataset, a Harman's one-factor test was conducted (Podsakoff and Organ, 1986). The 35.6% variance explained by a single factor shows that common method bias is not a major concern in this study.

3.2. Measures

Measures for IC stocks were developed by Kianto and colleagues based on the sources shown in Table 2. These scales were tested to ensure their operational validity and psychometric robustness. All measures are based on five-point Likert scales (1: strongly disagree, 5: strongly agree) and all the constructs proposed are reflective in nature. Table 2 shows the specific items used in each latent variable.

3.3. Statistical analysis

Descriptive analyses were performed using SPSS 23 software to show the degree of development of each specific item and of each latent variable within each of the samples under study (high-tech versus low-tech firms). Additional *t*-tests were then carried out to identify significant variation of values between groups.

The research hypotheses were subsequently tested by means of structural equation modelling based on partial least squares (PLS-Graph software 3.0; Chin and Frye, 2003), and a multigroup analysis was carried out to determine whether path coefficients differed significantly between high-tech and low-tech firms.

4. Results

4.1. Descriptive analysis

Table 3 shows the mean and standard deviation of each of the items making up the latent variables, as well as the average value of each of the constructs. Human capital is the only latent variable in which significant differences arise between high-tech and low-tech firms. In particular, employees' skills and expertise are significantly higher in high-tech companies compared with low-tech firms.

In addition, the degree of development of each IC component within each sample ('intra-group comparison') is very similar, as is the degree of product/service and managerial innovation performance.

Regarding correlations between latent variables (Table 5), none of them are excessively high. Indeed, the highest correlation found is 0.574.

4.2. Measurement model evaluation

Because all constructs were deemed to be reflective, individual item reliability (i.e. indicators' loading above 0.707), construct reliability (i.e. composite reliability above 0.8), convergent validity (i.e. average

Table 2. Constructs and measures

Constructs and measures	Sources	Item wording
Size	–	
(control variable)		Natural logarithm of the number of employees.
Industry	–	
(control variable)		Manufacturing firm = 1; Service firm = 0.
Human capital (reflective)	Bontis, 1998; Yang and Lin, 2009.	
HC1		Our employees are highly skilled at their jobs.
HC2		Our employees are highly motivated in their work.
HC3		Our employees have a high level of expertise.
Structural capital (reflective)	Kianto, 2008; Kianto et al., 2010.	
SC1		Our company has efficient and relevant information systems to support business operations.
SC2		Our company has tools and facilities to support cooperation between employees.
SC3		Our company has a great deal of useful knowledge in documents and databases.
SC4		Existing documents and solutions are easily accessible.
Internal relational capital (reflective)	Kianto, 2008; Yang and Lin, 2009.	
IRC1		Different units and functions within our company – such as R&D, marketing and production – understand each other well.
IRC2		Our employees frequently collaborate to solve problems.
IRC3		Internal cooperation in our company runs smoothly.
External relational capital (reflective)	Kianto, 2008	
ERC1		Our company and its external stakeholders – such as customers, suppliers and partners – understand each other well.
ERC2		Our company and its external stakeholders frequently collaborate to solve problems.
ERC3		Cooperation between our company and its external stakeholders runs smoothly.
Prod./Serv. innovation perf. (reflective)	Weerawardena, 2003	
PIP		Compared with its competitors, how successfully has your company managed to create products and services for customers over the past year?
Managerial innovation perf. (reflective)	Weerawardena, 2003	
MIP		Compared with its competitors, how successfully has your company managed to create new management practices over the past year?

variance extracted or AVE over 0.5) and discriminant validity (i.e. constructs sharing more variance with their own indicators than with other constructs) were verified (Tables 4 and 5).

As both tables reveal, all parameters show adequate values, excepting the loadings of two indicators: HC2 in the case of product/service innovation in high-tech and low-tech firms (0.653 and 0.648, respectively) and IRC1 in the case of product/service innovation in low-tech firms (0.691). As they are very close to the established acceptable limit for individual item reliability (0.707), both indicators were retained.

4.3. Structural model evaluation

Table 6 shows the extent to which hypotheses 1 through 4 are satisfied in both high-tech and low-tech

Table 3. Descriptive analysis

Items	Mean HT	SD HT	Mean LT	SD LT	Mean dif.	t-value	*P*-value
HC1	4.209	0.5763	3.745	0.6868	**0.4646**	**4.930**	**.000**
HC2	3.453	0.7920	3.309	0.6883	0.1450	1.305	.193
HC3	4.012	0.6416	3.809	0.5541	**0.2031**	**2.278**	**.024**
HC	3.891	0.5150	3.621	0.5233	**0.2709**	**3.496**	**.001**
SC1	3.698	0.9588	3.681	0.8061	0.1680	0.128	.898
SC2	3.709	0.8794	3.553	0.8503	0.1561	1.210	.228
SC3	3.884	1.0107	3.691	0.9507	0.1922	1.315	.190
SC4	3.628	0.9336	3.574	0.9559	0.0534	0.379	.705
SC	3.730	0.7842	3.625	0.7412	0.1046	0.920	.359
IR1	3.605	0.9490	3.596	0.7804	0.0089	0.069	.945
IR2	3.918	0.8621	3.819	0.7327	0.0985	0.826	.410
IR3	3.512	0.9670	3.649	0.8514	−0.1373	−1.007	.315
IR	3.682	0.8324	3.689	0.6823	−0.0056	−0.049	.961
ER1	3.905	0.6516	3.851	0.7178	0.0537	0.520	.603
ER2	3.894	0.7241	3.766	0.7248	0.1282	1.182	.239
ER3	3.659	0.7489	3.713	0.7567	−0.0539	−0.479	.633
ER	3.817	0.6043	3.777	0.6286	0.0409	0.441	.660
PIP	3.553	0.7793	3.391	0.9716	0.1616	1.225	.222
MIP	3.388	0.6564	3.409	0.8876	−0.0204	−0.175	.861

firms, as well as the amount of variance explained (R^2) for each endogenous construct (innovation performance).

Table 6 shows that human capital positively and significantly affects both product/service and managerial innovation in high-tech firms, whereas its influence on innovation in low-tech companies is non-significant. Thus, hypotheses H1ai and H1bi are satisfied, whereas hypotheses H1aii and H1bii are rejected. The influence of structural capital on innovation is always positive and significant with one exception: product/service innovation in high-tech firms. Hence, hypotheses H2aii, H2bi and H2bii are accepted, whereas hypothesis H2ai is rejected. In contrast, the direct influence of internal relational capital on innovation is never significant. Therefore, hypothesis H3 is fully rejected. Finally, the direct influence of external relational capital on innovation is only significant for product/service innovation. Consequently, hypothesis H4ai and H4aii are accepted, and hypotheses H4bi and H4bii are rejected.

Table 7 shows the results of the multigroup analysis. The degree of influence of human capital on product/service innovation is significantly larger in high-tech firms than in low-tech companies and it is also very close to being significantly larger in managerial innovation. Thus, hypothesis H5a is satisfied, but hypothesis H5b is not. Conversely, the influence of structural capital on both product/service and managerial innovation is significantly lower in high-tech firms than in low-tech companies. Hence, hypothesis H6 is fully accepted. No significant differences were found for internal relational capital between high-tech and low-tech firms. Therefore, hypothesis H7 is rejected. The same is true for external relational capital, which was predicted by hypothesis H8. Thus, that hypothesis is accepted.

Regarding innovation type, as both product/service and managerial innovation are present in both high-tech and low-tech firms, a multigroup test is not needed. Table 6 shows that the influence of human capital on product/service and managerial innovation is very similar in high-tech (0.207 versus 0.184) and in low-tech firms, although in this case its influence is non-significant. Therefore, hypothesis H9 is satisfied. However, the degree of influence of structural capital on innovation is noticeably larger for managerial innovation than for product/service innovation in both high-tech (0.270 versus 0.054) and low-tech firms (0.511 versus 0.358). Hence, hypothesis H10 is accepted. Regarding internal relational capital, its influence on innovation is equally irrelevant in all cases, whereas the influence of external relational capital is larger on product/service innovation than on managerial innovation in both high-tech (0.211 versus 0.082) and low-tech (0.238 versus 0.125) firms. Thus, hypothesis H11 is rejected, while hypothesis H12 is accepted.

Table 4. Measurement model evaluation Part I

Constructs and measures		PIP in HT	PIP in LT	MIP in HT	MIP in LT
Size	ρ_c	1.000	1.000	1.000	1.000
	AVE	1.000	1.000	1.000	1.000
Size	Loadings	1.000	1.000	1.000	1.000
Industry	ρ_c	1.000	1.000	1.000	1.000
	AVE	1.000	1.000	1.000	1.000
Industry	Loadings	1.000	1.000	1.000	1.000
Human capital	ρ_c	0.815	0.847	0.793	0.833
	AVE	0.598	0.653	0.565	0.627
HC1	Loadings	0.821	0.931	0.601	0.720
HC2		0.653	0.648	0.849	0.896
HC3		0.833	0.820	0.782	0.748
Structural capital	ρ_c	0.886	0.899	0.899	0.897
	AVE	0.664	0.690	0.691	0.686
SC1	Loadings	0.870	0.754	0.823	0.821
SC2		0.710	0.849	0.813	0.866
SC3		0.719	0.882	0.775	0.846
SC4		0.936	0.832	0.907	0.778
Internal relational capital	ρ_c	0.904	0.886	0.922	0.893
	AVE	0.760	0.725	0.798	0.738
IRC1	Loadings	0.771	0.692	0.880	0.727
IRC2		0.909	0.951	0.866	0.918
IRC3		0.926	0.890	0.932	0.918
External relational capital	ρ_c	0.884	0.882	0.882	0.890
	AVE	0.718	0.714	0.715	0.731
ERC1	Loadings	0.814	0.797	0.766	0.903
ERC2		0.840	0.896	0.883	0.782
ERC3		0.886	0.816	0.882	0.875
Prod./Serv. innovation perf.	ρ_c	1.000	1.000		
	AVE	1.000	1.000		
PIP	Loadings	1.000	1.000		
Managerial innovation perf.	ρ_c			1.000	1.000
	AVE			1.000	1.000
MIP	Loadings			1.000	1.000

Notes: ρc: composite reliability; AVE: average variance extracted; PIP: Product/Service innovation performance; MIP: Managerial innovation performance; HT: High-tech; LT: Low-tech.

Finally, regarding control variables, firm size is the only variable that exerts significant influence on innovation (more specifically, on product/service innovation) in high-tech firms. As can be observed, the smaller the high-tech company, the better the product/service innovation performance.

4.4. Post hoc analyses

Several IC components do not exert a significant direct influence on innovation (Hypotheses 1–4), raising the question about the real meaning of these results: is this because the affected components are truly irrelevant or because their influence may take place through other IC components? To disentangle this, we verified whether each non-significant IC component in the full model exerted a significant influence on innovation when taken in isolation. If such were the case, a mediation effect could be operating, whereas if not, the component under study is definitely irrelevant.

These post hoc analyses reveal that, in the case of product/service innovation, structural capital and internal relational capital are definitely irrelevant in high-tech companies, whereas the same happens with human capital and internal relational capital in low-tech firms (Figure 1).

Table 5. Measurement model evaluation Part II (discriminant validity)

Product/service innovation in high-tech firms	1	2	3	4	5	6	7
1. Size	(1.000)						
2. Industry	0.323	(1.000)					
3. Human capital	−0.060	−0.269	(0.773)				
4. Structural capital	−0.193	−0.172	0.336	(0.815)			
5. Internal relational capital	0.030	−0.122	0.456	0.502	(0.818)		
6. External relational capital	−0.064	−0.237	0.441	0.296	0.405	(0.847)	
7. Prod./Serv. innovation perf.	−0.370	−0.162	0.267	0.179	0.061	0.276	(1.000)

Product/service innovation in low-tech firms	1	2	3	4	5	6	7
1. Size	(1.000)						
2. Industry	−0.015	(1.000)					
3. Human capital	−0.002	−0.007	(0.808)				
4. Structural capital	0.047	0.134	0.479	(0.831)			
5. Internal relational capital	−0.065	0.058	0.558	0.517	(0.851)		
6. External relational capital	0.043	0.048	0.328	0.350	0.321	(0.845)	
7. Prod./Serv. innovation perf.	0.003	0.080	0.111	0.367	0.162	0.312	(1.000)

Managerial innovation in high-tech firms	1	2	3	4	5	6	7
1. Size	(1.000)						
2. Industry	0.323	(1.000)					
3. Human capital	−0.056	−0.191	(0.752)				
4. Structural capital	−0.193	−0.186	0.438	(0.831)			
5. Internal relational capital	0.028	−0.112	0.488	0.494	(0.893)		
6. External relational capital	−0.065	−0.232	0.433	0.250	0.400	(0.846)	
7. Managerial innovation perf.	0.030	−0.114	0.357	0.375	0.300	0.246	(1.000)

Managerial innovation in low-tech firms	1	2	3	4	5	6	7
1. Size	(1.000)						
2. Industry	−0.015	(1.000)					
3. Human capital	0.049	−0.069	(0.792)				
4. Structural capital	0.045	0.140	0.466	(0.828)			
5. Internal relational capital	−0.068	0.050	0.574	0.517	(0.859)		
6. External relational capital	0.018	0.051	0.407	0.345	0.303	(0.855)	
7. Managerial innovation perf.	0.065	0.063	0.208	0.488	0.177	0.260	(1.000)

Notes: Diagonal elements are the square root of the variance shared between the constructs and their measures, relative to the amount due to measurement error (AVE). Off-diagonal elements are the correlations among constructs. For discriminant validity, diagonal elements should be larger than off-diagonal elements.

However, in the case of managerial innovation, internal and external relational capital appear to affect innovation through their influence on human capital and structural capital in high-tech firms (see Figure 2), whereas in low-tech companies, human capital, internal relational capital and external relational capital could be affecting innovation through their influence on structural capital (see Figure 3).

Table 6. Structural model evaluation

		Exogenous constructs						
		Size	Industry	HC	SC	IRC	ERC	R^2
PIP in HT	Beta	**−0.345**	0.049	**0.207**	0.054	−0.130	**0.211**	23.52%
	t-value	**3.0647**	0,4215	**1.6477**	0.2907	0.8950	**1.6194**	
	P-value	**.0011**	.3368	**.0500**	.3857	.1856	**.0530**	
PIP in LT	Beta	−0.026	0.021	−0.118	**0.358**	−0.037	**0.238**	18.84%
	t-value	0.3141	0.2069	0.9082	**2.8877**	0.2212	**2.3241**	
	P-value	.3768	.4181	.1821	**.0020**	.4125	**.0103**	
MIP in HT	Beta	0.110	−0.041	**0.184**	**0.270**	0.036	0.082	20.58%
	t-value	1.1989	0.4157	**1.5851**	**2.0173**	0.2846	0.6034	
	P-value	.1156	.3389	**.0568**	**.0221**	.3880	.2733	
MIP in LT	Beta	0.033	−0.011	−0.020	**0.511**	−0.111	0.125	25.95%
	t-value	0.3797	0.1117	0.1582	**5.0745**	0.8486	1.0063	
	P-value	.3522	.4556	.4372	**.0000**	.1983	.1574	

Notes: *P*-values based on t_{499}, one-tailed test.

To analyse the degree of significance of these potential indirect effects, bootstrapping techniques were used by means of PLS-Graph software. For high-tech firms (Table 8), the results obtained support the existence of an indirect influence of internal relational capital through human and structural capital on managerial innovation, as well as supporting the existence of such an influence of external relational capital through human capital, but not through structural capital. Finally, for low-tech firms (Table 9), the results obtained support the existence of an indirect influence of human capital and internal relational capital on managerial innovation through structural capital, but not for external relational capital.

5. Discussion

This study has analysed how IC components influence product/service and managerial innovation in high and low-tech companies. The extant literature has largely overlooked differences in technology level and innovation type when analysing the IC–innovation relationship. However, this study has demonstrated that such differences must be considered.

In the case of product/service innovation, external relational capital boosts innovation regardless of the technology level of the firm. Both high- and low-tech companies must build solid relationships with customers, suppliers and strategic partners to create successful new products and services. On the contrary, internal relationships seem irrelevant for product/service innovation in both high- and low-tech firms. This contrasts with the widely held assumption that internal networks enhance innovation (Carmona-Lavado et al., 2010; Wang and Chen, 2013); thus, practice does not always carry out the relationship between internal relational capital and innovation.

A key difference between high- and low-tech firms when developing product/service innovation concerns the role of human and structural capital. Human capital has a significant influence on product/service innovation in high-tech companies, whereas structural capital has a larger influence in low-tech firms. Along

Table 7. Multigroup analysis

	Exogenous constructs	Beta (HT)	Beta (LT)	t-value	*P*-value
Product/ Service innovation performance	Size	**−0.345**	**−0.026**	**2.3218**	**.0103**
	Industry	0.049	0.021	0.1832	.4274
	Human capital	**0.207**	**−0.118**	**1.8024**	**.0360**
	Structural capital	**0.054**	**0.358**	**1.3904**	**.0825**
	Internal relational capital	−0.130	−0.037	0.4187	.3378
	External relational capital	0.211	0.238	0.1653	.4344
Managerial innovation performance	Size	0.110	0.033	0.6132	.2700
	Industry	−0.041	−0.011	0.2160	.4145
	Human capital	0.184	−0.020	1.1884	.1176
	Structural capital	**0.270**	**0.511**	**1.4626**	**.0721**
	Internal relational capital	0.036	−0.111	0.8095	.2093
	External relational capital	0.082	0.125	0.2354	.4070

Notes: *P*-values based on t_{499}, one-tailed test.

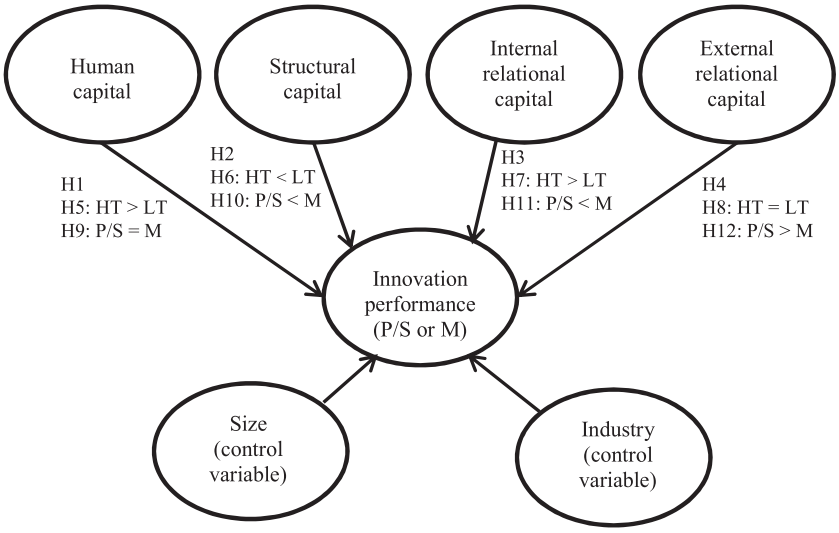

Figure 1. Research model.

with Delgado-Verde et al. (2015), highly qualified and skilful employees play a major role in companies managing complex knowledge (Schilling, 2011) that should be frequently renovated (De Carolis, 2010). Moreover, the heavier reliance of low-tech firms on explicit knowledge (which can be easily codified and stored in databases; Nonaka and Takeuchi, 1995) compared with high-tech companies explains the relevance of structural capital in low-tech firms. Additionally, size exerts a negative impact in high-tech companies as large firms are less agile to make decisions and implement innovations (Nooteboom, 1994).

Regarding managerial innovations, structural capital plays a pivotal role in both high- and low-tech firms. The development of new management practices and organizational methods, among others, benefit greatly from knowledge codification. This is

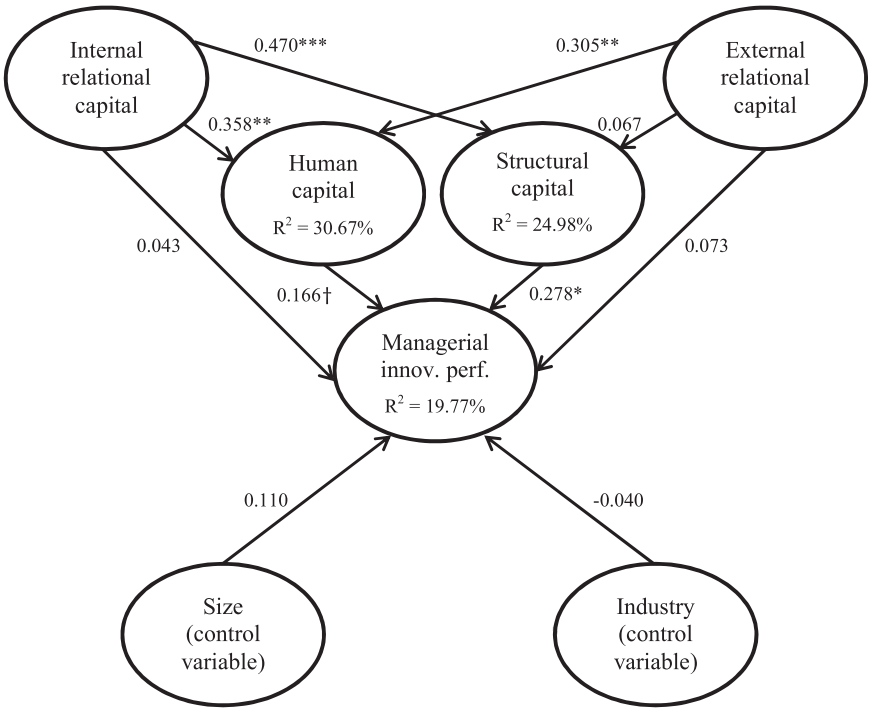

Figure 2. Post hoc analyses: Potential indirect effects on MIP in HT firms. Notes: ***$P < .001$, **$P < .01$, *$P < .05$, †$P < .1$ (based on t_{499}, one-tailed test).

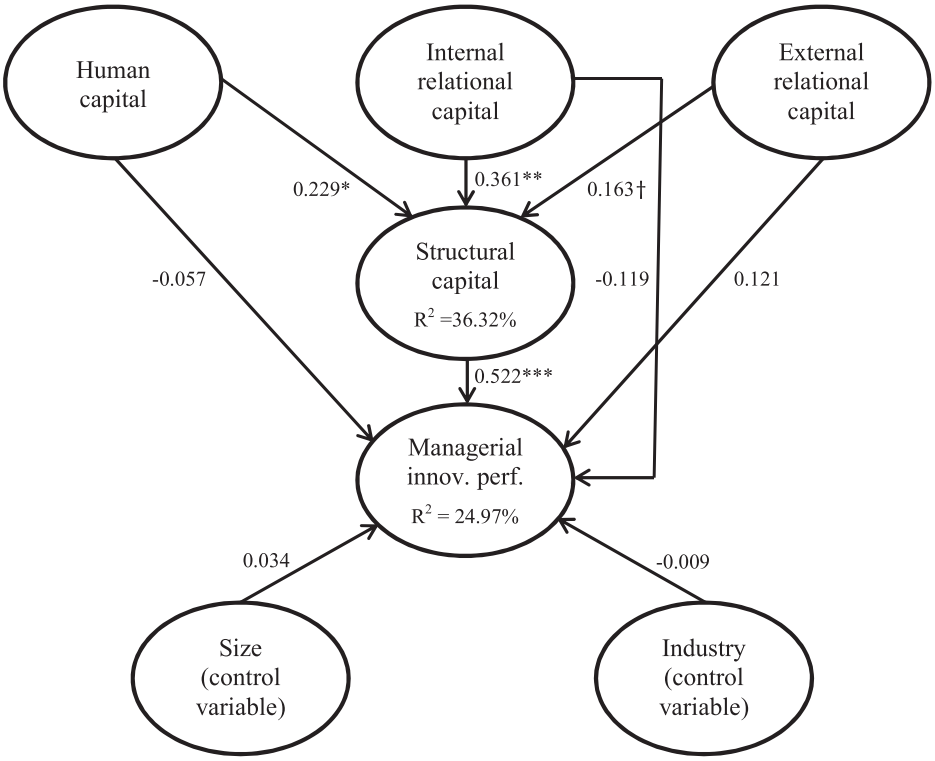

Figure 3. Post hoc analyses: Potential indirect effects on MIP in LT firms. Notes: ***$P < .001$, **$P < .01$, *$P < .05$, †$P < .1$ (based on t_{499}, one-tailed test).

especially true in low-tech firms which primarily utilise explicit knowledge (Schilling, 2011), and thus, knowledge that is easy to codify and transfer (Nonaka and Takeuchi, 1995).

With regard to high-tech firms, human capital, the firm's most relevant knowledge asset (Wright et al., 1994), plays a prominent role in boosting managerial innovations. Additionally, human capital is greatly enhanced by the knowledge generated from the relationships among employees (internal relational capital) and by the relationships of the company with external agents (external relational capital). Moreover, the relationships among employees (internal relational capital) also contribute to strengthening structural capital. Consequently, though managerial innovations have an internal-to-the-firm approach (Damanpour and Aravind, 2012), the relationships among employees do not per se influence innovation; however, they contribute to enhancing both employees' qualifications and motivation as well as the codified knowledge of the company. Moreover, interactions with external agents increase employees' qualification and motivation; thus, although the internal-to-the-firm approach is characteristic of managerial innovations, employees benefit from knowledge coming from outside the boundaries of the company for the development of

Table 8. Post hoc analyses: Exploring potential indirect effects of IRC and ERC through HC and SC in MIP in HT firms

	Indirect effect of IRC on MIP through HC	Indirect effect of ERC on MIP through HC	Indirect effect of IRC on MIP through SC	Indirect effect of ERC on MIP through SC
Indirect effect	0.059	0.051	0.131	0.019
t-value	2.3671	1.6679	1.9444	0.3523
P-value	.0183	.0960	.0524	.7247
Mediation	Yes	Yes	Yes	No
Direct effect sign.	Non-significant	Non-significant	Non-significant	NA
Type of mediation	Full	Full	Full	NA

Notes: *P*-values based on t_{499}, two-tailed test.

Table 9. Post hoc analyses: Exploring potential indirect effects of HC, IRC and ERC through SC in MIP in LT firms

	Indirect effect of HC on MIP through SC	Indirect effect of IRC on MIP through SC	Indirect effect of ERC on MIP through SC
Indirect effect	0.120	0.188	0.085
t-value	1.7781	2.4067	1.3014
P-value	.0760	.0165	.1937
Mediation	Yes	Yes	No
Direct effect sign.	Non-significant	Non-significant	NA
Type of mediation	Full	Full	NA

Notes: *P*-values based on t_{499}, two-tailed test.

organizational systems more suitable for managing complex knowledge (Schilling, 2011) that should be frequently renovated (De Carolis, 2010).

Considering low-tech firms, human capital, as well as internal and external relational capital, promote managerial innovation by means of structural capital. Even though human capital is fundamental for enhancing innovation (Carmona-Lavado et al., 2013), the lower complexity of the knowledge managed by low-tech firms (Schilling, 2011) justifies the role of employees' knowledge and motivation as mere promoters of structural capital. As for high-tech companies, the knowledge generated in the relationships among employees has no direct influence on innovation; however, this knowledge should be codified and stored in firm's databases and information systems to enhance innovation. Similarly, external relationships between employees and external agents directly promote structural capital. The influence of both internal and external relational capital when enhancing managerial innovations contrasts with the internal-to-the-firm approach characteristic of these types of innovations. Thus, it may be that either more contingency variables are affecting the IC–innovation relationship or that managerial innovations present more nuanced characteristics that should be deeply explored, or both.

6. Conclusions

This article focuses on the intellectual capital antecedents of product/service and managerial innovation in high- and low-tech companies. Our findings demonstrate that the IC–innovation linkage differs depending on (a) the type of innovation studied, and (b) the technology level of the innovating organization. Regarding innovation type, the obtained results align with those of Damanpour (1987), showing that different innovation types are not equally related to the same organisational factors. Our findings demonstrate that product/service and managerial innovation need different combinations of IC components. This clearly reinforces the relevance of considering different types of innovation. Regarding technology level, this study confirms the argument of Reed et al. (2006) that context influences how knowledge resources are used in value creation. This study demonstrates that differences set by technology level on such resources influence how IC affects innovation.

Overall, the article makes two main contributions. First, it points out the knowledge-based differences ingrained in various innovation types. Contrary to other studies addressing the IC–innovation relationship, this article places the differences between product/service and managerial innovation in a prominent position. Scholars in the field of innovation management may find this article useful in exploring the specific IC antecedents of product/service and managerial innovation on one hand, and based on that learning, in discovering more nuanced differences between product/service and managerial innovation, on the other.

Second, this article extends the discussion on the contingency perspective of IC initiated by Subramaniam and Youndt (2005) and Reed et al. (2006). This perspective is based on the assumption that the impact of IC on performance varies in differing contexts (Drazin and Van de Ven, 1985). Our study expands the understanding of the contingency issues that influence how intellectual capital supports innovation by pointing out how the IC–innovation link plays out in the case of product/service versus managerial innovation and high-tech versus low-tech firms.

6.1. Managerial implications

Bearing in mind that product/service and managerial innovation in high- and low-tech firms are differently affected by IC, managers should adopt targeted IC management. Managers should be aware that product/service and managerial innovations need different IC antecedents and that innovation is not equally promoted in high- and low-tech companies. In the

following, suggestions for enhancing each of the IC components analysed in this article are proposed.

It is highly recommended that managers continually perform human capital audits in order to discover the real gaps embedded in employees' qualifications, skill base and motivation. Taking into consideration the type of innovation the company wants to develop and the technology level of the firm, managers should first identify what their employees need; thus, the actions they take will be optimally aligned with the existing human capital gap.

Because structural capital is largely enhanced by other IC components, managers should have a clear idea of the type of innovation they want to create and the firm's technology level; this informs which other IC components will boost structural capital. Thus, practitioners will more efficiently use the limited resources they have for promoting innovation. Additionally, because structural capital contains knowledge that will be used by the employees of the company, it is of utmost importance to take into consideration employees' opinion when improving existing databases and information systems.

Regarding internal relational capital, managers should avoid taking for granted that as long as employees have trusting relationships and share useful knowledge, new products and services will be easily developed. Instead, managers should understand that internal relationships may not be crucial for developing certain types of innovations and should organise their limited resources accordingly.

Finally, promotion of external relationships is highly dependent on the industry to which the company belongs. Some sectors are very active in organizing workshops and conferences where professional firms gather together and share knowledge. Moreover, maintaining regular interactions with customers through meetings, phone calls, questionnaires and lotteries, among others, could provide relevant knowledge for innovating.

6.2. Limitations and future research

The research reported here has some limitations. First, the sample analysed consisted only of Spanish firms. Consequently, some of the findings could be affected by national characteristics. Thus, future research should consider testing this model in other national contexts.

Second, data was provided by only one person in each firm. However, a Harmon one-factor test was conducted (Podsakoff and Organ, 1986), which revealed that common method effects are not contaminating the results presented here.

Third, this article focuses on four IC components. Future research could enlarge the models developed here by including other components, such as renewal capital (Kianto et al., 2010) or entrepreneurial capital (Erikson, 2002). Additionally, there are probably other important contingency variables (e.g. manufacturing versus services firms) and other innovation types (e.g. business model innovation and process innovations) that could be analysed.

Lastly, since innovation is intrinsically grounded in knowledge, future research could explore the influence of innovation on strengthening IC. Indeed, Marqués et al. (2006) suggested that it is innovation that actually feeds IC, rather than the other way around. Case study methodology could be applied to examine the causality of the innovation–IC linkage in depth, which might offer valuable insights concerning the ways innovation affects a company's knowledge base.

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ORIGINAL ARTICLE

Exploring the role of human capital, renewal capital and entrepreneurial capital in innovation performance in high-tech and low-tech firms

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Abstract According to past research, intellectual capital (IC) is a key driver of innovation performance and subsequent competitive advantage. Given the human nature of innovation activities (i.e. human beings produce innovations), human capital (HC) deserves special attention. Although researchers in the past have analysed the HC–innovation linkage, we still do not have a detailed understanding of how specific human capabilities affect innovation. Furthermore, the technology level of the firm could generate major differences in the HC–innovation relationship as it influences both the type of knowledge prevalent within the company and the radicalness of the innovations developed. Nevertheless, former literature has largely omitted technology level when studying the IC–innovation linkage. To fill this research gap, this study examines the role of human attributes, including knowledge, skills and motivation (i.e. traditional HC), learning capability (i.e. renewal capital) and entrepreneurial attitude (i.e. entrepreneurial capital) on innovation in high-tech versus low-tech companies. To that end, survey data from 180 Spanish companies were analysed by means of structural equation modelling based on partial least squares. The results obtained confirm that the influence of HC, renewal capital and entrepreneurial capital on innovation differs depending on the technology level.

Keywords Intellectual capital · Human capital · Renewal capital · Entrepreneurial capital · Innovation performance · Technology level

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Introduction

The need for innovation in the contemporary business environment has been extensively discussed in the literature. Globalisation, intense competition, technological advances and changes in the competitive environment contribute to extreme and ongoing uncertainty, making innovation a crucial driver of organisational success, superior performance and smart response to environmental change in achieving and sustaining competitive advantage (e.g. Nonaka and Takeuchi 1995; Tidd et al. 2005).

As innovation involves creating new knowledge (Du Plessis 2007) or combining existing knowledge in new ways (Hargadon and Sutton 1997; Galunic and Rodan 1998; Fleming and Sorenson 2001), the knowledge resources organisations own or have access to—that is, intellectual capital (IC)—are relevant antecedents of innovation. Indeed, the relationship between IC and innovation has been widely studied (e.g. Subramaniam and Youndt 2005; Wu et al. 2007; Leitner 2011; Bornay-Barrachina et al. 2012). In particular, human capital is commonly seen as the most fundamental knowledge asset of an organisation (Wright et al. 1994). As innovation implies using and producing knowledge, human-related resources are crucial in this regard.

Existing studies of the IC–innovation linkage have tended to examine the human side of intangibles from a rather superficial perspective, usually in terms of general

attributes such as professional qualifications, skill base and employee motivation. Other more specific human capabilities that may well be relevant in this context have to date been almost ignored. In the broader innovation management literature, two types of IC seem especially promising in this respect: entrepreneurial attitudes among organisational employees, referred to as entrepreneurial capital (Erikson 2002), and learning capabilities, representing an organisation's renewal capital (Kianto et al. 2010).

As the knowledge resources needed for these productive activities have been shown to differ according to an organisation's technology level (Nelson and Wright 1992; De Carolis 2010; Rosenbloom 2010; Schilling 2011), it seems likely that the impact of human, entrepreneurial and renewal capital on innovation may also differ among firms with different levels of technological sophistication. Similarly, the greater focus of high-tech companies on radical innovation may require a different combination of IC elements. However, previous studies on the knowledge-related antecedents of innovation have either addressed only high-tech (Wu et al. 2007; Hsu and Fang 2009; Martín-de Castro et al. 2013) or low-tech companies (Alegre et al. 2012; Fernández-Mesa and Alegre 2015) or fail to distinguish firms' technology level at all (Wu et al. 2008; Camelo-Ordaz et al. 2009; Calisir et al. 2013). In other cases, the studies carried out combine high- and low-tech firms but do not pay attention to the differences among them (Wang and Chen 2013; Chen et al. 2015). It seems likely that distinguishing between high-tech and low-tech firms can provide a more fine-grained analysis of how the human aspects of IC affect innovation.

In sum, to gain a fuller understanding of the knowledge-based drivers of innovation, we argue that the human side of innovation activity deserves further investigation, encompassing employees' entrepreneurial attitude and capability to learn and renovate the company knowledge base as well as their qualifications, expertise and motivation. The purpose of this article is to deepen the current understanding of these human components of innovation activity across high-tech and low-tech companies. Grounding our case in a set of hypotheses informed by existing theory, we explore this issue by statistically analysing survey data collected from 180 Spanish companies.

Theoretical background and hypotheses

Innovation and intellectual capital (human, entrepreneurial and renewal capital)

For present purposes, *innovation* is conceptualised as the outcome of a creative process materialised in the form of products and services, production processes, management and marketing practices and business models (Schumpeter 1934). Innovation implies the creation of something new, entailing the development of new knowledge (Du Plessis 2007) or some new combination of existing knowledge (Hargadon and Sutton 1997; Galunic and Rodan 1998; Fleming and Sorenson 2001). As such, innovation is fundamentally a knowledge-based issue, grounded in the ability to create, manage and maintain knowledge (e.g. Cohen and Levinthal 1990; Tidd et al. 2005).

As innovation is a function of a firm's knowledge resources and related processes, its main antecedents seem likely to include IC components. A wide range of literature has already demonstrated this IC–innovation linkage (e.g. Wu et al. 2007; Leitner 2011; Alegre and Chiva 2013). IC can be defined as the set of knowledge assets that a company owns or has access to and manages for sustainable competitive advantage (Youndt et al. 2004; Subramaniam and Youndt 2005).

The most common classification characterises IC as comprising human, structural and relational capital (Bontis 1998). More specifically, IC consists of the combined knowledge embedded in employees' education and experience (human capital), information systems and codified knowledge (structural capital) and in the firm's webs of relationships (relational capital). Because knowledge is created by and stored mainly within individuals, human resources play an important role in driving innovation (De Winne and Sels 2010). Indeed, structural and relational forms of capital can be understood to arise from employees' generative activities, making human capital the core of IC (Bontis 1998; Wu et al. 2007).

To further specify the role of human resources as carriers of IC for innovation, we propose that human capital should be complemented by two further types of IC: entrepreneurial capital and renewal capital. Entrepreneurial capital refers to employees' ability to identify business opportunities, take risks and make difficult decisions (Erikson 2002), and renewal capital refers to their ability to learn and update the company's knowledge base (Kianto et al. 2010). As both are likely human-related bases of IC for innovation, it is proposed that to capture the human aspect of innovation from an IC perspective, three types of IC should be analysed.

1. *Human capital* (HC)—This is the sum of a company's knowledge, abilities and motivation as embodied in its workers (Edvinsson and Malone 1997; Subramaniam and Youndt 2005; Chen et al. 2015). Employees are the sole owners of HC, and firms can benefit from this in exchange for a salary (Roos et al. 1998). HC is a relevant enhancer of innovation as it positions the company to scan for new knowledge and so advance its knowledge frontiers (Leitner 2011; Martín-de Castro et al. 2013).

2. *Entrepreneurial capital* (EC)—It encompasses abilities that include identifying business opportunities, making difficult decisions, taking risks and showing initiative (Erikson 2002). Entrepreneurship-oriented firms exhibit a managerial attitude that favours frequent or radical innovation, proactive decision-making and risk taking (Alegre and Chiva 2013; Fernández-Mesa and Alegre 2015). EC enhances innovation by encouraging movement from a comfort zone of business as usual towards risk taking and challenging knowledge frontiers.
3. *Renewal capital* (RNC)—This includes employees' ability to learn and to update the company's knowledge base (Kianto et al. 2010). Being learning-oriented means being actively committed to learning as a key survival factor, having a shared vision of the firm's goals and being open-minded—that is, accommodating diverse viewpoints, questioning shared assumptions and promoting continuous innovation (Li et al. 2010).

Given the evidence that a firm's technology level influences the type of knowledge to be managed in terms of degree of complexity (Schilling 2011), tacitness (Nelson and Wright 1992; Rosenbloom 2010) and frequency of renovation (De Carolis 2010), it is also reasonable to propose that the role of human-related IC components in enhancing innovation will differ between high-tech and low-tech firms. In the next section, the relationships between these constructs are further explored and associated hypotheses are elaborated.

Hypotheses

Representing employees' knowledge and motivation (Bontis 1998; Chen et al. 2015), HC is intrinsically related to entrepreneurial capital. According to Stevenson and Jarillo (1990), 'It is individuals who carry out entrepreneurial activities, no matter how they are defined' (p. 21). Hence, individuals' characteristics are pertinent explanatory variables of entrepreneurial behaviour. Schuler (1986) considers behaviours, attitudes and other general (rather than specific) features as the only personal characteristics affecting entrepreneurial activity. However, according to Stevenson and Jarillo (1990) personality, background, skills and related specific characteristics also matter. Thus, employees' skills, qualification and motivation are proposed to affect entrepreneurial capital.

H1 Employees' level of qualification and motivation (HC) will determine their entrepreneurial attitude (EC).

The ability and willingness to identify opportunities, to be proactive and to take risks are of particular relevance in companies that have developed continuous learning capability (Kianto 2008). By being active and open in searching for new opportunities, by anticipating change and by taking risks, a firm can move into new knowledge domains that reinvigorate their capacity for learning. It follows that the 'actualised learning capability of the firm' (i.e. RNC) (Kianto et al. 2010, p. 309) is likely to be influenced by EC. On that basis, the following hypothesis is proposed:

H2 Employees' level of entrepreneurial attitude (EC) will determine their capability to learn and renovate the company's knowledge base (RNC).

In addition, RNC is affected by employees' knowledge and motivation (HC). Hsu and Fang (2009) demonstrated that 'a firm investing more in human capital will gain better quality employees, helping to enhance its organizational learning capability' (p. 673). In the same vein, Kianto et al. (2010) noted that RNC 'represents how well the organisation can utilise its human, structural and relational capital in order to foster continuous learning' (p. 309). For that reason, employees' qualifications, skills and motivation (HC) represent a point of departure for learning. Highly qualified and motivated employees can draw on a solid knowledge base and are willing to expand their knowledge frontiers.

Hypotheses 1 and 2 imply that HC influences learning capacity through its impact on EC (mediation hypothesis). However, as there is enough evidence to support a direct relationship between HC and RNC, we suggest that HC may exert an additional effect on RNC beyond that through EC. On that basis, the following hypothesis is proposed:

H3 Employees' level of entrepreneurial orientation (EC) partially mediates the relationship between their level of qualification and motivation (HC) and their ability to learn and to renovate the company's knowledge base (RNC).

The firm's ability to learn and to renovate its knowledge base (which clearly depends on the learning capability of its employees) has been widely linked to innovation (Hurley and Hult 1998; Aragón-Correa et al. 2007; Hsu and Fang 2009). As innovation involves the creation of new knowledge (Du Plessis 2007) or new combinations of existing knowledge (Hargadon and Sutton 1997; Galunic and Rodan 1998; Fleming and Sorenson 2001), it is likely to be affected by the company's ability to renew its existing knowledge. In terms of RNC, excellence means demonstrating high capability in acquiring and integrating relevant knowledge, which will be applied in innovation, enabling the company to achieve superior performance in that domain (Hsu and Fang 2009). On that basis, the following hypothesis is proposed:

H4 Employees' ability to learn and to renovate the company's knowledge base (RNC) will enhance innovation performance.

Employees' entrepreneurial attitude has been consistently linked to innovation performance (Shum and Lin

2010; Kollmann and Stöckmann 2014; Wong 2014). According to hypotheses 2 and 4, this effect is mediated by RNC (employees' ability to learn and to renovate the company's knowledge base). At the same time, previous studies have established that particular characteristics of EC (e.g. innovativeness, risk taking and proactivity) impact directly on innovation performance. According to Wong (2014), innovativeness stimulates employees 'to think differently and do things differently' (pp. 231–232). In a similar vein, Lumpkin and Dess (1996) argued that innovativeness 'reflects a firm's tendency to engage in and support new ideas, novelty, experimentation, and creative processes that may result in new products, services or technological processes' (p. 142). In other words, innovativeness spurs companies to be creative and to try new ideas as a point of departure for innovating. However, without risk taking, innovation activity cannot advance. Risk is intrinsically linked to innovation because 'the market potential of innovative products is highly uncertain' (Wong 2014, p. 232), making risk taking crucial for innovation. In addition, proactivity—the ability to shape the surrounding environment, to anticipate market needs and to enter emerging markets (Lumpkin and Dess 1996)—is a key driver of innovation (Wong 2014), as it stimulates the firm to address future market demands. In this sense, EC is seen to directly influence innovation beyond the impact through RNC. On that basis, the following hypothesis is proposed:

H5 Employees' ability to learn and to renovate the company's knowledge base (RNC) partially mediates the relationship between employees' level of entrepreneurial attitude (EC) and innovation performance.

Focusing on the relationship between HC and innovation performance as formulated in the above hypotheses, it seems likely that employees' entrepreneurial attitude and learning capability mediate the relationship between HC and innovation. However, as HC 'is a source of innovation' (Bontis 1998, p. 65), it seems worthwhile to assess the direct influence of HC on innovation. As the knowledge owned by a firm's employees (HC) necessarily affects the kinds of products and services developed, the ability to innovate is likely to depend on the firm's HC (Cabello-Medina et al. 2011). On that basis, the following hypothesis is proposed:

H6 Employees' level of entrepreneurial attitude (EC) and their ability to learn and to renovate the company's knowledge base (RNC) partially mediate the relationship between employees' level of qualification and motivation (HC) and innovation performance.

Finally, a company's technology level is known to influence the type of knowledge it can process. The knowledge of high-and low-tech companies differs in the following regards. First, high-tech firms tend to manage more complex knowledge with many underlying components and many interdependencies between them (Schilling 2011). This probably enhances the relevance of well-qualified HC for innovation. Second, the knowledge in high-tech companies is mainly tacit (Nelson and Wright 1992; Rosenbloom 2010) and therefore difficult to codify and transfer (Nonaka and Takeuchi 1995). Likewise, high-tech firms should renovate their knowledge base at frequent intervals (De Carolis 2010), which increases the relevance of RNC and the proactivity and risk taking associated with EC. Finally, the greater emphasis in high-tech companies on radical or disruptive (i.e. high risk) innovations may further increase the relevance of EC. On that basis, the following hypothesis is proposed:

H7 The technology level of the firm will affect the strength of the previously described relationships.

Research methods

Sample and data collection

The study population comprised 1289 Spanish firms with 100 employees or more whose financial accounts were on the SABI database. In total, 700 companies were contacted by phone (confidentiality assured) during the data collection period (October 2013–February 2015). Of these, 180 companies participated in the project (response rate: 25.71%) by answering a structured questionnaire. Most of the respondents were human resource managers (67.22%) or heads of other departments (18.33%).

Measures

The scales for IC variables were developed by Kianto and colleagues (cf. Inkinen et al. 2017), and the scale for innovation performance was adopted from Weerawardena (2003) (see Table 1). In terms of technology level, firms were classified following OECD and Eurostat criteria, which categorise companies according to their average R&D intensity for the period 1991–1999 against aggregate OECD R&D intensities (R&D expenditure divided by value-added and R&D expenditure divided by production). Those industries with a higher average R&D intensity on both indicators were classified as high or medium-high technology industries, and those returning lower values were categorised as medium-low and low-technology industries (OECD 2011).

As small firms are more agile than large ones in terms of innovation (Nooteboom 1994), and the nature of innovation may change from one industry to another (Lee 2005; Jiang et al. 2012), size (the natural logarithm of the number

Table 1 Measurement model evaluation Part I (individual item reliability, construct reliability and convergent validity)

Constructs and measures	Models	
	High-tech firms	Low-tech firms
Size	$\rho_c = 1.000$	$\rho_c = 1.000$
(control variable)	AVE = 1.000	AVE = 1.000
	Loadings	Loadings
Natural logarithm of the number of employees	1.0000	1.0000
Industry	$\rho_c = 1.000$	$\rho_c = 1.000$
(control variable)	AVE = 1.000	AVE = 1.000
	Loadings	Loadings
Manufacturing firm = 1; Service firm = 0	1.0000	1.0000
Human capital (HC)	$\rho_c = 0.810$	$\rho_c = 0.856$
(control variable, reflective)	AVE = 0.588	AVE = 0.665
	Loadings	Loadings
HC1 Our employees are highly skilled at their jobs	0.7064	0.8338
HC2 Our employees are highly motivated in their job	0.7776	0.7769
HC3 Our employees have a high level of expertise	0.8123	0.8342
Entrepreneurial capital (EC)	$\rho_c = 0.868$	$\rho_c = 0.880$
(reflective)	AVE = 0.568	AVE = 0.596
	Loadings	Loadings
EC1 Risk taking is regarded as a positive personal quality in our company	0.7257	0.7368
EC2 Our employees take deliberate risks related to new ideas	0.7107	0.8081
EC3 Our employees excel in identifying new business opportunities	0.7675	0.6815
EC4 Our employees show initiatives	0.8216	0.8024
EC6 Our employees have the courage to make bold and difficult decisions	0.7366	0.8213
Renewal capital (RNC)	$\rho_c = 0.893$	$\rho_c = 0.926$
(reflective)	AVE = 0.676	AVE = 0.757
	Loadings	Loadings
RNC1 Our company has acquired a great deal of new and important knowledge	0.7775	0.8657
RNC2 Our employees have acquired many important skills and abilities	0.8363	0.8246
RNC3 Our company can be described as a learning organisation	0.8558	0.9286
RNC4 The operations of our company can be described as creative and inventive	0.8171	0.8581
Innovation performance (IP)	$\rho_c = 0.835$	$\rho_c = 0.900$
(reflective)	AVE = 0.504	AVE = 0.643
Compared to its competitors, how successfully has your company managed to create innovations in the following areas over the last year?	Loadings	Loadings
IP1 Products and services for customers	0.6741	0.8106
IP2 Production methods and processes	0.7056	0.8440
IP3 Management practices	0.6465	0.8178
IP4 Marketing practices	0.7470	0.7847
IP5 Business models	0.7690	0.7505

ρ_c composite reliability, *AVE* average variance extracted

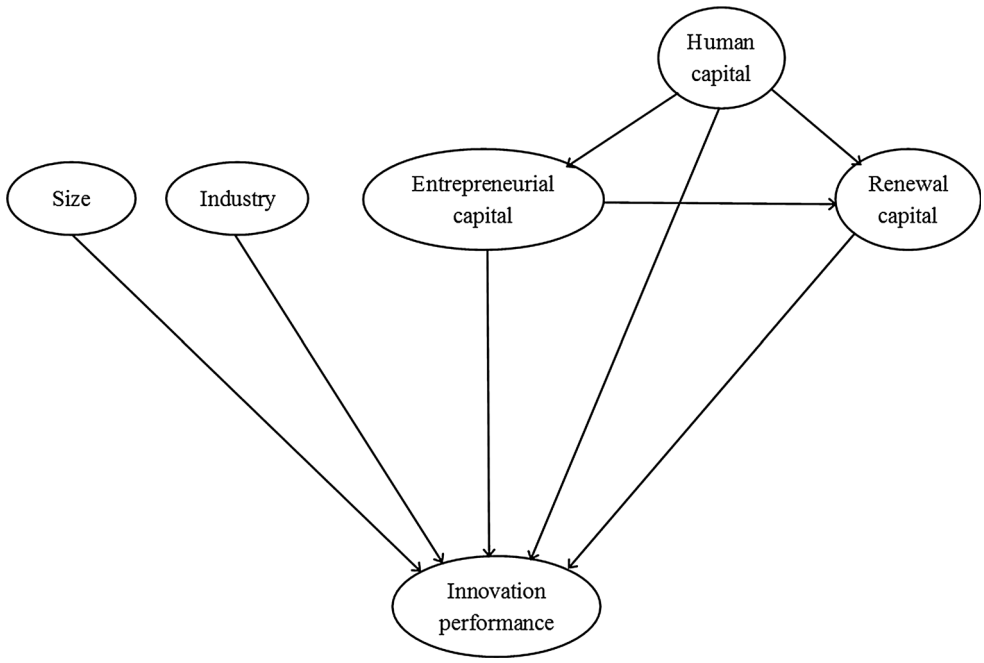
of employees) and industry (manufacturing or service) were added as control variables.

Statistical analysis

To gain a detailed understanding of how technology level affects the linkage between human aspects of innovation activity and innovation performance, a model was built (see Fig. 1) and run for the two samples (i.e. high- and low-technology firms) ($N = 86$ and $N = 94$).

Structural equation modelling based on partial least squares was applied using PLS-Graph software (Chin and Frye 2003), and a multigroup analysis was performed to identify relevant differences between both samples.

Fig. 1 Model



Results

Measurement model evaluation

The model run for both samples was assessed for validity and reliability. As the indicator EC5 showed poor values, it was eliminated from the final model. Tables 1, 2 and 3 present the results of the evaluation of the measurement model after removing this indicator.

Structural model evaluation

Before running the full model, preliminary models were run in each subsample to assess the direct influence of the independent variables on the dependent variables in the absence of mediators. In particular, the following direct links were tested: HC–innovation, EC–innovation and HC–RNC. As all direct links are statistically significant, the first condition for mediation to exist is fully satisfied.

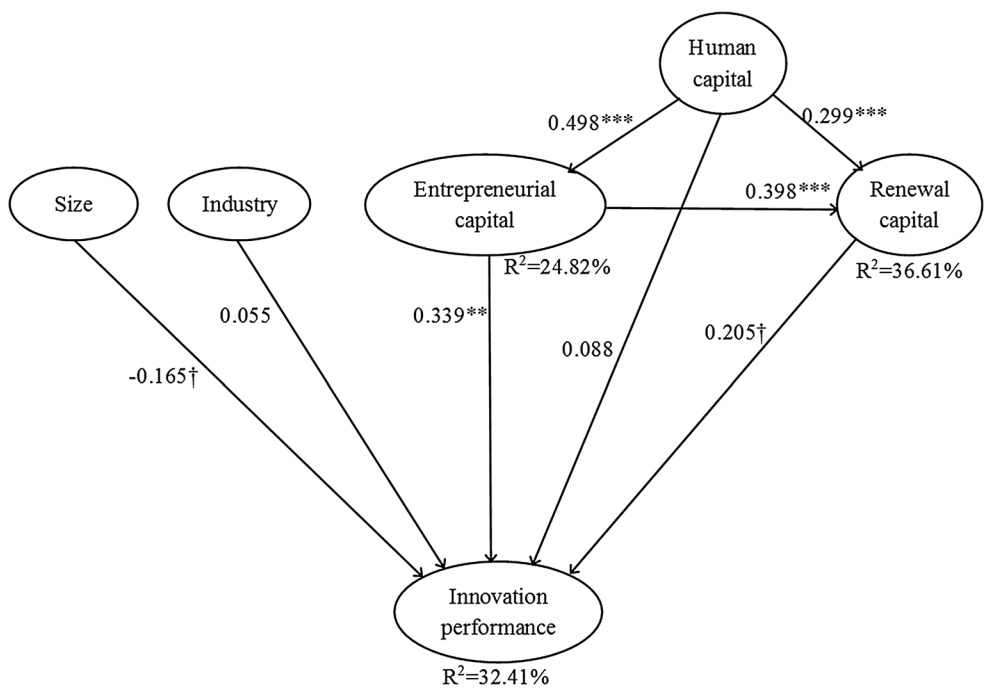
Table 2 Measurement model evaluation Part II (discriminant validity)

	Size	Industry	HC	EC	RNC	Innovation
High-tech firms						
Size	(1.000)					
Industry	0.323	(1.000)				
HC	−0.059	−0.227	(0.767)			
EC	−0.152	−0.141	0.498	(0.754)		
RNC	−0.069	−0.210	0.497	0.547	(0.822)	
IP	−0.218	−0.110	0.356	0.513	0.434	(0.710)
Low-tech firms						
Size	(1.000)					
Industry	−0.015	(1.000)				
HC	0.033	−0.036	(0.815)			
EC	0.092	0.208	0.488	(0.772)		
RNC	0.065	0.088	0.416	0.634	(0.870)	
IP	0.079	0.055	0.184	0.334	0.638	(0.802)

Diagonal elements (values in parentheses) are the square root of the average variance extracted (AVE). The remaining elements are the correlations between constructs. Diagonal elements should be higher than the correlations in the same row and column

Table 3 Summary of results: evaluation of the measurement model

Attributes to check	High-tech firms	Low-tech firms
Individual item reliability	All loadings showed values higher than 0.707 with the exception of HC1 = 0.7064; IP1 = 0.6741; IP2 = 0.7056; IP3 = 0.6465. These indicators have been retained, as the values are close to the established limit	Indicator loadings presented values higher than 0.707 with the exception of EC3 = 0.6815. This indicator has been retained in the model, as the value is close to the established limit
Construct reliability	Composite reliability (ρ_c) is higher than 0.8 in all cases	
Convergent validity	All constructs are above 0.5 in terms of the average variance extracted (AVE)	
Discriminant validity	All constructs share more variance with their own indicators than with other constructs	



***p < 0.001, **p < 0.01, *p < 0.05, †p < 0.1 (based on t_{499}, one-tailed test).

Fig. 2 Model: high-tech

On running the full model (see Figs. 2, 3; Table 4), it can be observed that HC does not directly promote innovation (both samples) but that its effect is mediated by EC and/or RNC.

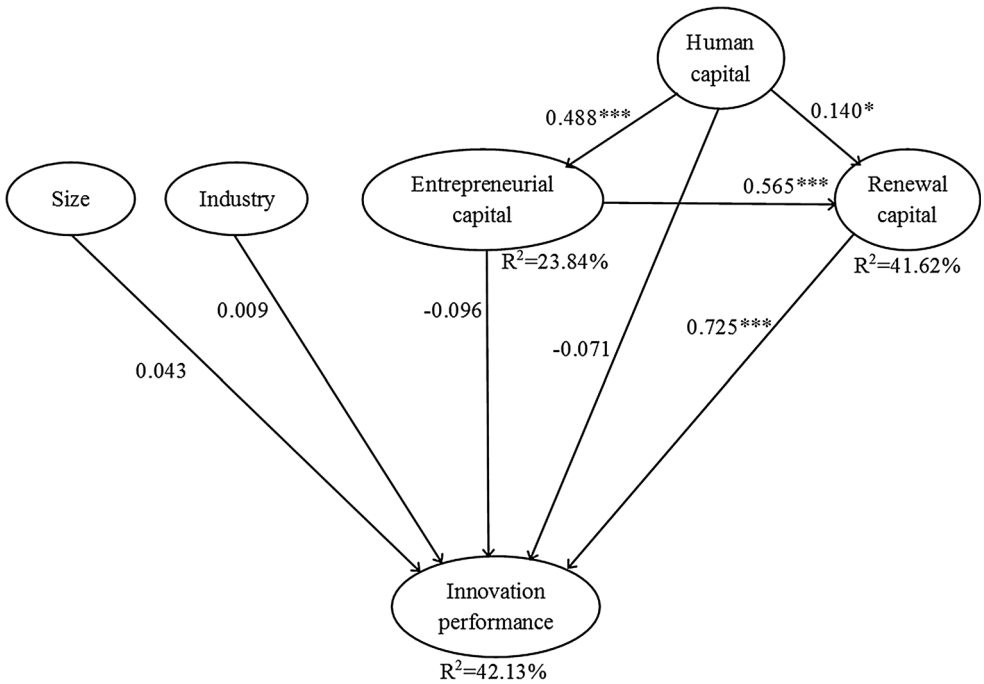
In high-tech companies, EC and RNC are significantly enhanced by HC and at the same time exert a direct influence on innovation (i.e. the second and third conditions for mediation are satisfied). It follows that EC and RNC wholly mediate the impact of HC on innovation. In addition, EC partially mediates the influence of HC on RNC, and RNC is a partial mediator in the EC–innovation linkage.

In low-tech firms, HC has a significant impact on both EC and RNC, and RNC is also boosted by EC. As RNC is the only component that directly enhances innovation, it completely mediates the impact of HC on innovation on the one hand and the impact of EC on innovation on the other. Additionally, EC partially mediates the connection between HC and RNC.

The multigroup test (Table 5) clearly shows that while the influence of EC on innovation is significantly higher in high-tech firms than in low-tech companies, the impact of RNC on innovation performance is significantly stronger in low-tech than in high-tech companies.

With regard to control variables, size exerts a significant negative impact on innovation in high-tech companies, but its effect becomes insignificant in low-tech firms. Industry

Fig. 3 Model: low-tech



***p < 0.001, **p < 0.01, *p < 0.05, †p < 0.1 (based on t_{499}, one-tailed test).

Table 4 Structural model evaluation

	Exogenous constructs					Variance explained (R^2)
	Size	Industry	HC	EC	RNC	
EC in HT						
Path			0.498***			24.82%
t value			6.6615			
RNC in HT						
Path			0.299***	0.398***		36.61%
t value			3.1087	3.1215		
IP in HT						
Path	−0.165†	0.055	0.088	0.339**	0.205†	32.45%
t value	1.5647	0.5956	0.6827	2.6394	1.4784	
EC in LT						
Path			0.488***			23.84%
t value			6.7128			
RNC in LT						
Path			0.140*	0.565***		41.62%
t value			1.6588	6.1051		
IP in LT						
Path	0.043	0.009	−0.071	−0.096	0.725***	42.10%
t value	0.5386	0.119	0.7852	0.6718	7.0034	

HT high-tech, *LT* low-tech

*** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$, † $p < 0.1$ (based on t_{499}, one-tailed test)

has no significant effect in either high-tech or low-tech companies.

In terms of the amount of variance explained, both models (32.41% in high-tech and 42.13% in low-tech) are well above the 10% threshold established by Falk and Miller (1992) for a model to be relevant.

Finally, the results support all hypotheses with the exception of hypothesis 5 for low-tech companies (full

Table 5 Multigroup test

Hypothesis	Path coef. HT	Path coef. LT	Standard error HT	Standard error LT	*t* value
Size–innovation	−0.165	0.043	0.1055	0.0790	−1.604†
Industry–innovation	0.055	0.009	0.0923	0.0757	0.390
HC–EC	0.498	0.488	0.0748	0.0727	0.096
HC–RNC	0.299	0.140	0.0962	0.0844	1.254
EC–RNC	0.398	0.565	0.1275	0.0925	−1.079
HC–innovation	0.088	−0.071	0.1289	0.0904	1.029
EC–innovation	0.339	−0.096	0.1284	0.1429	2.262*
RNC–innovation	0.205	0.725	0.1387	0.1035	−3.055**

HT high-tech, *LT* low-tech

*** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$, † $p < 0.1$ (based on t_{499}, one-tailed test)

rather than partial mediation of RNC in the relationship between EC and innovation) and hypothesis 6 for both high- and low-tech firms (full mediation of EC and RNC in the relationship between HC and innovation in high-tech companies; no mediation of EC and full mediation of RNC in low-tech firms).

Discussion

The aim of the present study was to deepen current understanding of the human aspects of innovation by analysing the influence of HC, EC and RNC in companies at different technology levels. The amount of variance explained by the model that includes only the HC–innovation linkage (used to test the first condition for mediation; not fully reported for reasons of space) is much lower than that obtained in the full model (20.19 vs. 32.45% for high-tech and 5.54 vs. 42.10% for low-tech). The inclusion of EC and RNC as additional components of IC therefore provides a more fine-grained understanding of the internal dynamics of human-related intangibles in innovation.

The results show that employees' level of qualification and motivation (HC) is a key determinant of EC and RNC in both high-tech and low-tech firms. This aligns with Schuler (1986) and Stevenson and Jarillo (1990) who stress the relevance of the entrepreneurs' personal characteristics as well as with existing evidence that strong HC provides a solid foundation on which to develop learning capabilities (Kianto et al. 2010).

The relevance of employees' knowledge base in boosting RNC (i.e. learning capability) is noticeably higher in high-tech companies. In both subsamples, the observed difference in the path coefficient linking HC to RNC is very close to significance (0.299 vs. 0.140), and this is further amplified for the total effect (i.e. adding the indirect effect of EC). In this case, a total value of $0.299 + (0.498 \times 0.398) = 0.663$ for high-tech firms compares to $0.140 + (0.488 \times 0.565) = 0.416$ for low-tech. This probably relates to the specific knowledge characteristics of high-tech companies (i.e. superior complexity, tacitness and speed of renovation [Nelson and Wright 1992; De Carolis 2010; Rosenbloom 2010; Schilling 2011)]), which increases the need for highly qualified employees.

The strong influence of EC on RNC should also be highlighted. This is stronger in the case of low-tech than in high-tech companies, although the difference is not significant. Being proactive, searching continuously for new opportunities and being willing to take risks are key attributes for enhancing learning, aligning with Kianto's (2008) finding that EC is relevant in learning-oriented firms.

Irrespective of technology level, the influence of HC on innovation is mediated by EC and/or RNC. In high-tech industries, identifying opportunities, taking risks and making difficult decisions (EC) influence innovation, both directly and through RNC. RNC helps to transform EC into innovation by fostering the acquisition of existing knowledge that enables the firm to exploit identified business opportunities. In addition, the strong direct link between EC and innovation can be explained by the type of innovation prevailing in high-tech firms. In such companies, radical or disruptive innovations (i.e. high risk innovations) tend to be more frequent than in low-tech, increasing the relevance of identifying new opportunities, taking risks and making difficult decisions. This also aligns with the need for more frequent renewal of the knowledge base (De Carolis 2010).

For low-tech firms, RNC is the only component of IC that exerts a significant direct influence on innovation. Once more, this may be a consequence of the type of innovation that predominates in these companies, as low-tech firms are more likely to develop incremental rather than radical innovations. Hence, acquiring existing knowledge (RNC) will not necessarily place the company behind its competitors and will promote incremental change. Nevertheless, as already mentioned, nurturing EC

is essential if learning opportunities are to be identified and grasped, so enhancing innovation.

Conclusions

In this study examining the human side of innovation from an IC perspective, the empirical findings confirm that the combination of HC, EC and RNC enhances innovation, and that these linkages are affected by the company's technology level. The study contributes to the literature on IC in two principal ways. First, by demonstrating the importance of EC and RNC as components of IC influencing innovation, it contributes to a more thorough understanding of the knowledge-based drivers of innovation. The finding that the impact of HC is mediated by these types of IC strongly supports their inclusion in models of IC, at least when studying innovation.

Second, the inclusion of technology level offers a more fine-grained understanding of the above relationships, as high- and low-tech companies differ in respect of how innovative human capital affects innovation.

In general, this more detailed understanding of the human IC antecedents of innovation responds to the call by Petty and Guthrie (2000) and Reed et al. (2006) to investigate how IC applies in practice. The research community will also benefit from this study as a stimulus for new and creative ways of combining IC components to better represent the intangibles that inform actual innovation. The results also show that contingency variables such as technology level may indeed influence the IC–innovation relationship.

From a practical perspective, promoting an entrepreneurial attitude among employees, enhancing learning and updating the knowledge base are crucial for innovation in high-tech companies. In low-tech firms, the capacity to learn and acquire new knowledge and skills is pivotal for boosting innovation. In both types of company, a qualified and motivated workforce and investment in upgrading employees' knowledge and skills is critical for the enhancement of both EC and RNC.

Finally, as the empirical study was confined to Spanish firms, caution should be exercised in generalising the findings to other contexts. Future studies can further deepen the understanding of the IC–innovation linkage by investigating the role of contingency variables other than technology level, as well as the relevance of other novel forms of IC such as trust capital. As noted by Costigan, Ilter and Berman (1998) (cited in Cesaroni et al. 2015), 'A high level of trust among colleagues generates an environment that supports calculated risk-taking and entrepreneurial orientation' (p. 74). Exploration of this link between trust capital and EC is likely to further enhance our understanding of innovation.

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Publication 4

Buenechea-Elberdin, M., Sáenz, J. and Kianto, A.
Knowledge management strategies, intellectual capital, and innovation performance: a comparison between high- and low-tech firms

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Knowledge management strategies, intellectual capital, and innovation performance: a comparison between high- and low-tech firms

Abstract

Purpose – *This study analyses the complementary role of structural and relational capital (as the outcomes of codification and personalisation knowledge management strategies) in renewal capital and innovation in high- and low-tech companies.*

Design/methodology/approach – *The primary data, which were collected through a structured questionnaire from 180 Spanish companies, are analysed using structural equation modelling based on partial least squares.*

Findings – *Overall, the study offers three fundamental findings. Firstly, it demonstrates the outstanding role of renewal capital as an intellectual capital (IC) component; secondly, it provides a conceptual analysis of the connection between knowledge management strategies and IC; and thirdly, it highlights the necessity of considering the technological level of the firm as a contingency variable affecting the IC–innovation relationship.*

Research limitations – *The study has three apparent limitations: The sample of firms is restricted to Spanish companies, data concerning the main study variables were collected from only one person at each firm, and not all of the possible components of IC were included in the research model.*

Practical implications – *Business practitioners can find useful guidelines for making efficient use of knowledge resources when boosting innovation performance, depending on the technological level of their firms.*

Originality/value – *Although many studies have tried to disentangle the IC–innovation connection, this study is unique, as it considers knowledge management strategies, a novel combination of IC components, and the level of technological sophistication in the same analysis.*

Keywords *Intellectual capital, Knowledge management strategies, Codification and personalisation strategies, Innovation, Technological level*

Paper type *Research paper*

1. Introduction

The current competitive landscape has been repeatedly described as globalised, turbulent, uncertain, changing and increasingly competitive (Carmona *et al.*, 2010; Wang and Chen, 2013; Chen *et al.*, 2014; Elsetouhi *et al.*, 2015). Companies operating in such an environment are forced to innovate to improve their performance (Chen *et al.*, 2014), be successful (Delgado-Verde *et al.*, 2015) and gain competitive advantages (Cabello-Medina *et al.*, 2011; Martín-de Castro *et al.*, 2013). Innovation is currently considered a *sine qua non* condition for corporate survival (Hsu and Fang, 2009; Delgado-Verde *et al.*, 2011).

Innovation involves the 'creation of new knowledge and ideas to facilitate new business outcomes' (Du Plessis, 2007, p. 21). The stock of knowledge resources a firm manages or to which it has access—that is, its intellectual capital (IC) (Youndt *et al.*, 2004)—is widely considered to be a key driver of innovation (Subramaniam and Youndt, 2005; Wu *et al.*, 2007; Carmona-Lavado *et al.*, 2010; Martín-de-Castro *et al.*, 2013). IC can be approached from a static and/or a dynamic perspective. The static view considers IC as a stock of knowledge, meaning that 'it is something that can be relatively easily identified, located, moved and traded, much like some

sort of a package, albeit an intangible one' (Kianto, et al., 2007, p. 344). The dynamic perspective holds that 'knowledge is understood as emerging from the ongoing interactions between the organisational members, and the focus is not on the intangible assets per se but on the organisational capabilities to leverage, develop and change intangible assets for value creation' (Kianto et al., 2007, p. 344).

From a static point of view, the existing literature has typically split IC into three components: employees' knowledge, skills, experience, and motivation constitute the so-called human capital (HC) (Edvinsson and Malone, 1997; Stewart, 1997; Bontis, 1998); explicit knowledge stored in databases and information systems is called structural capital (SC) (Wu *et al.*, 2007) and knowledge accumulated in the networks of the firm's relationships is called relational capital (RC) (Edvinsson and Malone, 1997; Nahapiet and Ghoshal, 1998). Recently, renewal capital (RNC) has been suggested as a new category of IC (Kianto *et al.*, 2010; Inkinen *et al.*, 2017). RNC is rooted in the founding literature on IC in which change and adaptation to future needs have already been highlighted (Edvinsson and Malone, 1997; Roos *et al.*, 1997; Sveiby, 1997). RNC represents a firm's ability to learn and, by doing so, renew its knowledge-base to adapt to the changing environment and remain competitive (Kianto *et al.*, 2010). RNC constitutes the 'actualized learning capability of the firm' (Kianto *et al.*, 2010, p. 309), and learning represents how knowledge can be renovated.

In line with this, knowledge management (KM) refers to 'all the activities that utilize knowledge to accomplish the organizational objectives' (Greiner *et al.*, 2007, p. 4), and KM strategies play a substantial role in the renovation of a firm's knowledge base. Hansen *et al.* (1999) made a distinction between two KM strategies: codification and personalisation. Codification involves adopting a people-to-documents approach, achieving the storage and dissemination of knowledge through efficient electronic-document systems (Hansen *et al.*, 1999). Companies following a codification strategy enhance their stock of explicit knowledge in the form of databases and information systems (i.e. SC). Thus, SC could be seen as the outcome of a codification-based KM strategy. Conversely, personalisation is based on a person-to-person approach in which networks of relationships are the principal instrument for transferring tacit knowledge (Hansen *et al.*, 1999). Firms pursuing a personalisation-based KM strategy enhance their RC. Thus, RC could be thought of as the outcome of a personalisation-based KM strategy.

To date, the field of IC has evolved to a second stage in which the main issue is the analysis of the influence of IC on a firm's effectiveness, innovation or competitive advantage (Martín-de-Castro *et al.*, 2011). However, the connection between KM strategies and knowledge resources has received limited attention, with some exceptions, such as Kianto *et al.* (2014), Handzic and Durmic (2015), Khadir-Poggi and Keating (2015), Rossi *et al.* (2016), Marzo and Scarpino (2016) and Zaragoza-Sáez *et al.* (2016). The dynamic approach to IC, which refers to how knowledge assets are leveraged, developed, managed and changed (Kianto, 2007), overlaps with KM. Both IC and KM relate to how knowledge is handled. However, in the literature, KM and IC have typically been studied as two disjoined streams of research (Kianto *et al.*, 2014). In this sense, the linkage between them deserves to be considered.

Moreover, the clear majority of studies investigating the way in which IC components influence innovation performance have concentrated on traditional IC categories; they do not include RNC. This finding is surprising considering that the concept of renewal was addressed by Edvinsson and Malone (1997), Roos *et al.* (1997) and Sveiby (1997). Therefore, a new and crucial question arises: What KM strategy (identified by whether it gives rise to SC or RC) is most effective in promoting RNC and subsequent innovation? Are both KM strategies equally relevant to enhancing renewal and innovation?

The technological level of the firm (or its level of technology sophistication) is related to its R&D intensity. The average R&D intensity is higher in high-tech industries than in low-tech industries (OECD, 2011). In terms of knowledge characteristics, high-tech firms deal with knowledge that is more complex (Schilling, 2011), mainly tacit (Nelson and Wright, 1992; Rosenbloom, 2014) and more rapidly changing (De Carolis, 2014). How, then, does this contingency factor influence the relationship between the outcomes of codification and personalisation-based KM strategies (SC and RC) and RNC, as well as the subsequent innovation?

Consequently, the purpose of this study is to analyse the complementary role of SC and RC as the manifestation of codification and personalisation outcomes in RNC and innovation in high- and low-tech companies. The contribution of this paper lies within the KM and IC fields. From an academic perspective, this research fills relevant gaps in the KM and IC literature by examining the crucial role played by RNC in the IC–innovation linkage and its underlying KM strategies. Including the technological level as a contingency variable paves the way for future studies in this field. For business practitioners, the study offers a more nuanced understanding of how scarce resources could be deployed to foster innovation performance.

The rest of the paper is organised as follows. The next section reviews the theoretical background of the study and presents the hypotheses to be tested. The subsequent sections explain in detail the research methods used and the results of the model. The final section presents the discussion and principal conclusions.

2. Theoretical background and hypotheses

2.1 Knowledge management strategies, traditional intellectual capital components, and renewal capital

Having become a key driver of competitiveness, knowledge is increasingly seen as a strategic resource which needs to be managed strategically. Knowledge strategy articulates the relationship between an organisation's competitive strategy and the organisation's intellectual resources and capabilities (Zack, 1999). Conversely, KM strategy refers to the guidelines, goals, resources, and long-term plans of KM programmes in a company (Bolisani and Bratianu, 2017). The KM literature embraces several typologies of strategies, amongst which the codification versus personalisation (Hansen *et al.*, 1999) distinction figures prominently. The codification/personalisation dichotomy deserves special attention because it is widely recognised in the field and covers other strategic distinctions, such as exploration/exploitation and human orientation/system orientation (López-Nicolás and Meroño-Cerdán, 2011). Furthermore, as Davenport and Völpel (2001) noted, this strategy distinction is intrinsically associated to another well-known dichotomy – that is, tacit versus explicit knowledge (Polanyi, 1966; Nonaka and Takeuchi, 1995).

Codification strategy takes place when 'knowledge is carefully codified and stored in databases, where it can be accessed and used easily by anyone in the company' (Hansen *et al.*, 1999, p. 1). Firms following this strategy focus on managing explicit knowledge (Davenport and Völpel, 2001; Greiner *et al.*, 2007), which 'can be expressed in words and numbers, and easily communicated and shared in the form of hard data, scientific formulae, codified procedures, or universal principles' (Nonaka and Takeuchi, 1995, p. 8). Knowledge is codified by means of the so-called people-to-documents approach, which implies obtaining knowledge created by a person, making it independent from that person, and reusing it for different aims (Hansen *et al.*, 1999). Hence, information technology systems which facilitate knowledge storage and reuse play an outstanding role (Hansen *et al.*, 1999).

Conversely, personalisation strategy deals with the communication of tacit knowledge amongst people (Ajith Kumar and Ganesh, 2011). Tacit knowledge includes 'subjective insights, intuitions, and hunches,' which are 'not easily visible and expressible' and are 'highly personal and hard to formalize' (Nonaka and Takeuchi, 1995, p. 8). For this reason, a person-to-person approach is needed for the exchange of tacit knowledge (Hansen *et al.*, 1999); this implies that knowledge is communicated by means of dialogue between individuals (López-Nicolás and Meroño-Cerdán, 2011). The role of information technology is to support communication amongst people (Hansen *et al.*, 1999; Greiner *et al.*, 2007), and this exchange of knowledge is produced through formal (organised meetings and corporate away days) and informal (coffee-break conversations) mechanisms (Storey and Kahn, 2010).

In consequence, KM strategies encompass how knowledge-related resources are managed in an organisation, thus constituting different ways of governing knowledge resources. In this way, knowledge is the object which must be managed to create greater value for the organisation. The strategic knowledge-related resources to which a company has access or manages to gain sustainable competitive advantages (Youndt *et al.*, 2004; Subramaniam and Youndt, 2005) comprise the IC of an organisation. IC is grounded on knowledge, as IC accounts for the knowledge resources which can be transformed into value and profits (Edvinsson and Sullivan, 1996; Sullivan, 1999).

Traditionally, IC has been divided into three main components – that is, HC, SC, and RC – which have been combined in two different ways. On one hand, a key distinction was made between HC and SC, the latter containing the relationships with customers, suppliers, and/or other stakeholders (Edvinsson and Sullivan, 1996; Edvinsson and Malone, 1997; Roos *et al.*, 1997). This two-way combination of IC components stressed the difference between thinking and non-thinking IC (Roos *et al.*, 1997). On the other hand, several researchers regarded relationships with customers, suppliers, and/or additional stakeholders as a relevant IC component. Therefore, SC was disaggregated, resulting in a tri-component framework consisting of employees or HC, internal structure or SC, and external structure (Bontis, 1996; Saint-Onge, 1996; Edvinsson and Malone, 1997; Stewart, 1997; Sveiby, 1997). Recently, RNC has been considered a new IC component, thus enlarging the traditional tri-component framework. The content scope of each component of IC is as follows:

Human capital refers to the knowledge which is accumulated in the individuals working in the company. Human capital encompasses employees' knowledge, skills, attitudes, experience, and motivation (Edvinsson and Malone, 1997; Stewart, 1997; Bontis, 1998). HC is 'the chief source of competitive advantage' (Roos and Roos, 1997, p. 413); however, HC cannot be owned by the company (Roos and Roos, 1997; Roos *et al.*, 1997; Sveiby, 1997).

Structural capital is the knowledge which is accumulated and distributed through the company's structures and processes, such as information systems, cultural traits, and management systems (Edvinsson and Malone, 1997; Stewart, 1997; Bontis, 1998). SC refers to explicit knowledge which is susceptible to being codified into documents and databases. In contrast to HC, SC 'is the part of the firm that remains when the human resource goes home' (Edvinsson and Sullivan, 1996, p. 360).

The study of RC has raised divergent views amongst researchers regarding the range of relationships considered. *Internal relational capital* (IRC) refers to the knowledge which is generated through and embedded in the networks of relationships amongst the employees of the company (Nahapiet and Ghoshal, 1998; Kianto and Waajakoski, 2010). *External relational capital* (ERC), in contrast, comprises the knowledge and resources residing in the webs of relationships the company maintains with external partners, such as customers, suppliers, other agents, and the local community (Edvinsson and Malone, 1997; Bontis, 1998). Although the

internal dimension is regularly discussed today, RC originally dealt with the external structure of the firm. This is the reason why mainstream scholars in the 1990s focussed mainly on the external side of the relationships, thus analysing the linkages with customers (Saint-Onge, 1996; Edvinsson and Malone, 1997; Stewart, 1997), customers and suppliers (Sveiby, 1997), and customers, suppliers, and other partners (Bontis, 1996; Roos *et al.*, 1997).

Finally, *renewal capital* represents the firm's ability to learn and to renovate its knowledge-base (Kianto *et al.*, 2010). Academic research has addressed organisational renewal using a wide range of headings, such as organisational change and development, organisational learning, knowledge creation, dynamic capability, continuous improvement, and renewal capability (Kianto, 2008). Whilst these terms come from different literatures, renewal has been part of the IC discussion since the late 1990s and, for this reason, we decided to stick to this literature stream (which constitutes the focus of our research) without considering other possible streams such as the organisational learning literature or the dynamic capabilities approach.

The well-known Skandia Navigator included 'Renewal and Development Focus' to represent 'what things the company is doing now to best prepare itself to grasp future opportunities' (Edvinsson and Malone, 1997, p. 111). Sveiby (1997) developed indicators of growth and renewal to measure the degree of change of employee competence, and internal and external structure. Roos *et al.* (1997, p. 51) considered 'renewal and development capital' a key part of structural capital which 'includes all the items that have been built or created and that will have an impact on future value but have not manifested that impact yet'. Along with these works, in which being ready for future changes was deemed necessary, RNC is proposed as the capacity to renovate the company's knowledge stocks so that the firm may deal with environmental changes and maintain its competitive position. Knowledge renewal implies learning, since the acquisition of new knowledge and skills is the only way previous cognition and behaviour can be updated. Accordingly, the ability to learn and to renovate the knowledge-base defines RNC (Kianto et al., 2010). Learning and knowledge renewal have become crucial for companies to compete in environments which are subject to rapid technological, regulatory, and competitive changes (Zollo and Winter, 2002). However, the existing body of literature has focused primarily on the traditional IC components, failing to analyse the renewal capability of companies as part of IC. RNC and the traditional IC components are closely interrelated, the latter being the base for knowledge renewal. In other words, what companies can learn and update depends on their previous use of HC, SC, and RC (Kianto *et al.*, 2010, p. 309).

Focusing on SC, the influence it exerts on RNC is obvious. Explicit knowledge which is codified and stored in a firm's databases, information systems, and written procedures is a typical foundation on which new knowledge can be constructed (Nonaka and Takeuchi, 1995). A company cannot learn if individual learning is not accumulated in repositories which are accessible to other employees (Argote and Miron-Spektor, 2011). As learning is required in knowledge renewal, well-developed structural capital seems to be necessary for updating the firm's knowledge stocks. Companies following a codification KM strategy are likely to gather and codify individual knowledge in databases and written materials which will be accessible for collective use (Storey and Kahn, 2010). Thus, strong SC (which results from a codification KM strategy) provides companies with easily-available knowledge which could be used to enhance RNC. Following this idea, the next hypothesis is proposed:

H1. Structural capital promotes renewal capital in (i) high- and (ii) low-tech firms.

IRC and ERC represent knowledge resources which are generated when tacit knowledge is shared inside and outside of the firm. Hsu and Fang (2009) consider relationships with customers, business partners, and research institutes to be appropriate means of acquiring new knowledge which could foster a firm's ability to learn. Learning and renovating the knowledge-base of the

company (RNC) depend on existing knowledge (Kianto *et al.*, 2010, p. 309), especially in the form of tacit cognitive knowledge (beliefs, ideas, and mental schemas) and tacit technical knowledge (capabilities and skills) (Bueno *et al.*, 2010). This tacit knowledge is accessible solely through person-to-person interactions, which are characteristic of a personalisation KM strategy which concentrates on 'dialogue between individuals, not knowledge objects in a database' (Hansen *et al.*, 1999, p. 2). On this basis, the following hypothesis is suggested:

H2. (a) Internal and (b) external relational capital foster renewal capital in (i) high- and (ii) low-tech firms.

2.2 Intellectual capital and innovation

Definitions of innovation are not in short supply. These definitions tend to concur on two aspects: innovation implies creating something new (Saénz and Aramburu, 2011), and innovation always includes the final commercialisation of the new creation, not only its invention (Tidd and Bessant, 2009). Furthermore, the type of innovation created could vary from products or services to production processes or business models, amongst others. The popular *Oslo Manual* (Organisation for Economic Co-operation and Development [OECD] and EUROSTAT, 2005), that follows the taxonomy ideated by Schumpeter (1983) in his theory of innovation, differentiates between product/service, process, marketing, and organisational innovation. Following these specificities, in this article, innovation is the creation, development, and commercialisation of new products, services, production processes, management and marketing practices, and business models.

Innovation and knowledge are intrinsically related, as the former implies the 'creation of new knowledge and ideas to facilitate new business outcomes' (Du Plessis, 2007, p. 21). As innovation 'is not directly available to all organizations at all times, but only to firms with the appropriate internal characteristics' (Aragón-Correa *et al.*, 2007, p. 356), the study of factors enabling innovation is indisputably relevant. In fact, the linkage between IC and innovation has been analysed extensively, resulting in numerous articles which demonstrate the influence of IC components on innovation performance at a single point in time (e.g. Subramaniam and Youndt, 2005; Hsu and Fang, 2009; Carmona-Lavado *et al.*, 2010; Martín-de-Castro *et al.*, 2013; Harlow, 2017). However, the majority of these studies are focused on HC, SC, and RC, leaving aside the influence of RNC on innovation performance.

Even though the RNC–innovation relationship has been under-explored, renewal and innovation had been connected in the seminal work by Edvinsson and Malone (1997). They defined 'innovation capital' as 'the renewal capability and the results of innovation' (Edvinsson and Malone, 1997, p. 35-36). Focusing on learning as a requisite which enables knowledge renewal, acquiring, distributing, interpreting, and accumulating knowledge in organisation's memory support the development of new products and processes (Sanz-Valle *et al.*, 2011); new products, processes, and administrative procedures (Jiménez-Jiménez *et al.*, 2008; Jiménez-Jiménez and Sanz-Valle, 2011); and individual- and organisational-level innovation performance (Wang and Ellinger, 2011). According to Bueno *et al.* (2010), innovation is promoted by learning, as the latter enables corporate renewal and impedes technological deadlock. Furthermore, learning outcomes (in terms of the knowledge, skills, and capacities acquired in the learning process), greatly promote the creation of products/services and internal operating practices (Aragón-Correa *et al.*, 2007; Bueno *et al.*, 2010). Consequently, the connection between renewal and innovation suggested by Edvinsson and Malone (1997), and the set of studies linking learning (as a key enabler of renewal) with innovation, provide solid grounds to suggest that RNC enhances innovation performance. In accordance with this rationale, the next hypothesis is proposed:

H3. Renewal capital fosters innovation performance in (i) high- and (ii) low-tech firms.

Turning to SC, evidence in the literature suggests that firms owning strong SC present higher levels of innovation. Knowledge repositories and advanced information systems contribute to the development of new products (Menor *et al.*, 2007; Wu *et al.*, 2007). More precisely, Han and Li (2015) have demonstrated that SC helps improve efficiency by means of coordinating a firm's culture, structure, and routines and by gathering relevant information to support decision-making. Companies with advanced SC have up-to-date knowledge repositories and databases, as well as relevant information systems which make the firms' innovation activities more efficient. As a result, it is proposed that SC exerts a significant influence on innovation performance beyond the impact SC has on RNC. On this basis, the following hypothesis is proposed:

H4. Structural capital promotes innovation performance in (i) high- and (ii) low-tech firms.

Furthermore, internal and external networks of relationships promote innovation. By means of IRC, employees share information and knowledge and communicate and interact with managers (Subramaniam and Youndt, 2005; Carmona-Lavado *et al.*, 2010), which leads to enhanced coordination, increased efficiency, and reduced lead-time. Conversely, cooperation with customers, suppliers, and strategic partners allows the company to obtain the necessary skills and resources to innovate more quickly, to be more flexible, and to share costs and risks (Schilling, 2011). Hence, IRC and ERC exert an additional influence on innovation beyond the impact they have on RNC. Accordingly, the next hypothesis is suggested:

H5. (a) Internal and (b) external relational capital foster innovation performance in (i) high- and (ii) low-tech firms.

The hypotheses described previously suggest that RNC partially mediates the influence of SC and both IRC and ERC on innovation performance. Hypotheses 1 and 2 propose that RNC (i.e. the mediator) is promoted by SC and RC (i.e. the independent variables), whilst hypothesis 3 suggests RNC is a relevant enhancer of innovation performance (i.e. the dependent variable). Finally, hypotheses 4 and 5 contend that SC, IRC, and ERC have additional direct effects on innovation performance.

In the same vein, previous studies suggest a mediating role for learning in the relationship between both SC and RC and innovation (Hsu and Fang, 2009; Zhang and Lv, 2015). For instance, supply chain learning has been found to totally mediate the linkage between SC and technological innovation and to partially mediate the relationship between internal and external social capital and technological innovation (Zhang and Lv, 2015). As RNC is the ability to learn and to renovate the knowledge-base (Kianto et al., 2010), these studies could also support a mediating role for RNC. Accordingly, the following hypothesis is suggested:

H6. The influence of structural and both (a) internal and (b) external relational capital on innovation performance is partially mediated by renewal capital in (i) high- and (ii) low-tech firms.

2.3 Technological level

The type of knowledge a company manages differs from firm to firm according to the technological level of a given company. As IC embodies the set of knowledge resources managed by a firm (Subramaniam and Youndt, 2005), it is logical to assume that high- and low-tech companies will differ in terms of the knowledge accumulated in various components of IC. In fact, some recent studies have proved the contingency role of technological level in the relationship between IC components and innovation performance (Buenechea-Elberdin *et al.*, 2017a, 2017b). However, the vast majority of research has disregarded how technology sophistication could affect the IC–innovation linkage (Buenechea-Elberdin, 2017).

Focusing on the degree of knowledge tacitness, a connection could be established between personalisation and codification strategies on the one hand and the level of technological sophistication on the other. A personalisation strategy is based on face-to-face interactions amongst individuals aiming to share tacit knowledge (Storey and Kahn, 2010); thus, high-tech companies, which largely manage tacit knowledge (Nelson and Wright, 1992; Rosenbloom, 2014), are more likely to reinforce IRC and ERC in renewing their knowledge base. On the contrary, low-tech firms, which deal mainly with explicit knowledge (Nelson and Wright, 1992; Rosenbloom, 2014), are more likely to leverage on a codification strategy which makes knowledge independent from the person who has developed it (Hansen *et al.*, 1999). Therefore, low-tech firms rely to a larger extent on SC when it comes to enhancing RNC.

Similarly, the degree of knowledge tacitness affects the relationships between SC, IRC, and ERC vis-à-vis innovation performance. As knowledge governed by low-tech firms is mainly explicit (Nelson and Wright, 1992; Rosenbloom, 2014) and, therefore, easy to codify and transfer (Nonaka and Takeuchi, 1995), innovation in these companies tends to rely on codified knowledge, databases, and information systems (SC) rather than on personal interactions (RC). By contrast, companies with a high level of technological sophistication deal largely with tacit knowledge (Nelson and Wright, 1992; Rosenbloom, 2014), which is difficult to codify, store, and transfer (Nonaka and Takeuchi, 1995). Thereby, IRC and ERC, instead of SC, play a key role in the enhancement of innovation in these firms.

As for the pace of knowledge renewal, high-tech firms operate in increasingly changing environments which make it necessary for companies to be able to frequently revise and update their knowledge-base (De Carolis, 2014). RNC is therefore more relevant for enhancing innovation in high-tech firms compared to low-tech companies.

To sum up, compared to low-tech firms, it is expected that renewal and innovation performance in high-tech companies depend to a larger extent on internal and external relationships, and that RNC is more relevant for innovation performance in such firms. In the case of low-tech companies, however, structural capital is likely to exert a larger influence on both renewal capital and innovation performance. As a result, the following is proposed:

H7. The technological level of the firm may increase or decrease the strength of the previously described relationships.

2.4 Control variables

This study considers size, industry, and HC as control variables. Small firms are flexible and agile due to their simpler hierarchical structure and their lack of complex procedures (Nooteboom, 1994). Whereas smaller companies usually have fewer resources than large companies (Nooteboom, 1994), this deficiency may be compensated, given the increasing relevance of co-operation amongst firms. Consequently, it is expected that size exerts a negative impact on innovation. In the case of industry, a distinction was made between manufacturing and service companies because the propensity to innovate might change from one industry to another (Lee, 2005; Jiang *et al.*, 2012).

Finally, we have also included HC as a control variable. According to the IC literature, HC is the cornerstone of IC and exerts a widely recognised impact on innovation performance (Cabello-Medina, *et al.*, 2011; Carmona-Lavado *et al.*, 2013). It is necessary to control for this variable so that the relationships which are investigated are not affected by the potential effect of HC.

Figure 1 summarises the research model.

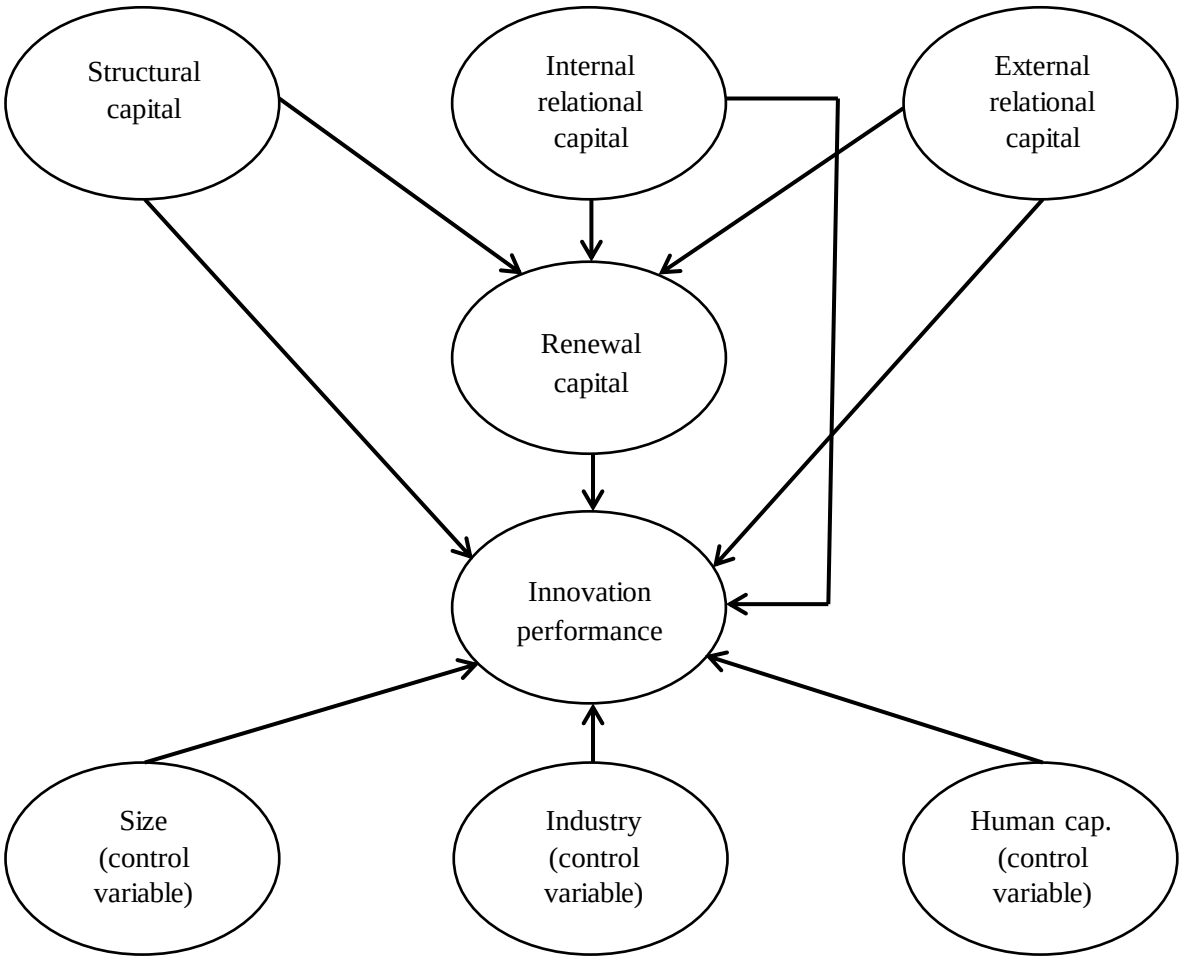


Figure 1. Research model

3. Research methods

3.1 Sample and data collection

The population considered in this study consists of Spanish companies with 100 or more employees. The *Sistema de Análisis de Balances Ibéricos* (SABI; System of Iberian Balance Sheet Analysis) database has been used to identify companies. Of the 1,289 firms which initially met the established criteria, only 700 were contacted by phone due to budget constraints. During the data collection period, from October 2013 to February 2015, firms were sequentially contacted, and confidentiality was guaranteed to all participants. The aim was to obtain a convenience sample which would allow comparing different types of companies (high- versus low-tech, large versus medium, manufacturing versus service) instead of obtaining a representative sample which would mirror the composition of the Spanish population of firms (i.e. we did not aim to reach conclusions at the country level but in terms of different types of companies). Hence, emphasis was placed on balancing manufacturing and service companies, large and medium firms, and high- and low-tech firms.

Companies were classified into high-tech or low-tech groups in accordance with the technology-intensity classification of industries developed by the *Instituto Nacional de Estadística* (INE; National Institute of Statistics), which follows the criteria set by the OECD and EUROSTAT. Industries showing higher R&D intensity were classified as high-tech, whereas the ones having lower R&D intensity were classified as low-tech (INE, 2001).

The complete sample comprised 180 firms (response rate: 25.71%) which took part by answering a structured questionnaire. The division into high- and low-tech resulted in 86 (47.78%) companies being deemed high-tech and 94 (52.22%) firms being deemed low-tech. Table 1 presents detailed information about the sectoral composition of the sample.

Regarding respondents' profiles, 89.44% were managers or directors holding a position of responsibility in their companies. Of these, 3.89% were managing directors, 67.22% were human resource managers, and 18.33% were heads of other departments. The remaining 10.56% of participants were regular employees who did not hold management responsibilities.

As data referring to all variables derive from the same self-reported survey, this could lead to the occurrence of what is known as 'common method bias' (Podsakoff *et al.*, 2003). To determine the extent of method variance in the dataset, a Harman's one-factor test was conducted (Podsakoff and Organ, 1986). The 35.14% variance explained by a single factor shows that common method bias is not a major concern in this study.

Table 1. Sample composition (1 of 2)

Industry	Frequency	Percentage
20 Manufacture of chemicals and chemical products	5	2.78%
21 Manufacture of basic pharmaceutical products and pharmaceutical preparations	3	1.67%
27 Manufacture of electrical equipment	3	1.67%
28 Manufacture of machinery and equipment n.e.c.	4	2.22%
29 Manufacture of motor vehicles, trailers and semi-trailers	14	7.78%
30 Manufacture of other transport equipment	2	1.11%
50 Motion picture, video and television programme production, sound recording and music publishing activities	3	1.67%
60 Programming and broadcasting activities	3	1.67%
61 Telecommunications	4	2.22%
62 Computer programming, consulting and related activities	35	19.44%
63 Information service activities	3	1.67%
72 Scientific research and development	7	3.89%
Medium-high and high technology subtotal	**86**	**47.78%**
10 Manufacture of food products	15	8.33%
11 Manufacture of beverages	5	2.78%
12 Manufacture of tobacco products	1	0.56%
13 Manufacture of textiles	1	0.56%
14 Manufacturing of wearing apparel	1	0.56%
15 Manufacture of leather and related products	2	1.11%
17 Manufacture of paper and paper products	1	0.56%
18 Printing and reproduction of recorded media	1	0.56%
22 Manufacture of rubber and plastic products	4	2.22%
23 Manufacture of other non-metallic mineral products	2	1.11%
24 Manufacture of basic metals	6	3.33%

Table 1 – Sample composition (2 of 2)

25 Manufacture of fabricated metal products, except machinery and equipment	7	3.89%
31 Manufacture of furniture	1	0.56%
32 Other manufacturing	1	0.56%
33 Repair and installation of machinery and equipment	1	0.56%
35 Electricity, gas, steam and air conditioning supply	1	0.56%
36 Water collection, treatment and supply	1	0.56%
41 Construction of buildings	1	0.56%
42 Civil engineering	2	1.11%
43 Specialised construction activities	1	0.56%
46 Wholesale trade, except of motor vehicles and motorcycles	3	1.67%
47 Retail trade, except of motor vehicles and motorcycles	1	0.56%
49 Land transport and transport via pipelines	8	4.44%
52 Warehousing and support activities for transportation	1	0.56%
55 Accommodation	3	1.67%
56 Food and beverage service activities	2	1.11%
58 Publishing activities	3	1.67%
70 Activities of head offices; management consultancy activities	2	1.11%
71 Architectural and engineering activities; technical testing and analysis	2	1.11%
74 Other professional, scientific and technical activities	3	1.67%
79 Travel agency, tour operator and other reservation service and related activities	1	0.56%
81 Services to buildings and landscape activities	2	1.11%
84 Public administration and defence; compulsory social security	1	0.56%
85 Education	1	0.56%
86 Human health activities	1	0.56%
87 Residential care activities	3	1.67%
88 Social work activities without accommodation	2	1.11%
Medium-low and low technology subtotal	**94**	**52.22%**
Total	**180**	**100.00%**

3.2 Measures

Measures for IC stocks have been developed by Kianto and colleagues (Inkinen *et al.*, 2014a, 2014b, 2017) and tested to ensure their operational validity and their psychometric robustness. Five-point Likert scales (where 1 = strongly disagree and 5 = strongly agree) were used for all relevant questions; the detailed wording of these items can be seen in Table 3.

3.3 Statistical analysis

Descriptive analyses have been carried out using SPSS 23 software to show the degree of development of each specific item and of each latent variable within each of the samples under study – that is, high-tech versus low-tech firms. T-tests were also conducted to identify statistically significant variations of values between groups.

The research hypotheses were then tested using structural equation modelling based on partial least squares (PLS-Graph software 3.0; Chin and Frye, 2003). The first stage of this analysis consists of evaluating the validity and reliability of the measurement model, and the second stage

assesses the structure of the model. In this second phase, the hypotheses proposed are tested. In addition, a multi-group analysis was carried out to determine whether the path coefficients differed significantly between high- and low-tech firms.

4. Results

4.1. Descriptive analyses

Table 2 shows the mean and the standard deviation of each of the items that comprise the latent variables, as well as the average value of each of the constructs. Latent variables are those that cannot be directly observed and should be inferred by means of sets of indicators. In this study, IC components and innovation performance are the latent variables.

HC and RNC are the only latent variables in which statistically significant differences arise between high- and low-tech firms: both IC components score significantly higher in the first group. Conversely, the degree of development of each IC component within each sample ('intra-group comparison') is very similar, except for RNC in low-tech firms, which is slightly lower than the other IC blocks in this group. Moreover, innovation performance is lower than IC in both types of companies.

Regarding the correlations between the latent variables (Table 4), none are excessively high. Indeed, the highest correlation is 0.637.

Table 2. Descriptive analysis

Items	Mean HT	SD HT	Mean LT	SD LT	Mean dif.	t-value	p-value
HC1	4.209	0.5763	3.745	0.6868	**0.4646**	**4.892**	**0.000**
HC2	3.453	0.7920	3.309	0.6883	0.1450	1.314	0.191
HC3	4.012	0.6416	3.809	0.5541	**0.2031**	**2.278**	**0.024**
HC	3.891	0.5150	3.621	0.5233	**0.2709**	**3.496**	**0.001**
SC1	3.698	0.9588	3.681	0.8061	0.1680	0.128	0.898
SC2	3.884	1.0107	3.691	0.9507	0.1922	1.315	0.190
SC3	3.628	0.9336	3.574	0.9559	0.0534	0.379	0.705
SC	3.736	0.8246	3.649	0.7673	0.8750	0.737	0.462
IRC1	3.605	0.9490	3.596	0.7804	0.0089	0.069	0.945
IRC2	3.918	0.8621	3.819	0.7327	0.0985	0.826	0.410
IRC3	3.512	0.9670	3.649	0.8514	-0.1373	-1.007	0.315
IRC	3.682	0.8324	3.689	0.6823	-0.0056	-0.049	0.961
ERC1	3.905	0.6516	3.851	0.7178	0.0537	0.520	0.603
ERC2	3.894	0.7241	3.766	0.7248	0.1282	1.182	0.239
ERC3	3.659	0.7489	3.713	0.7567	-0.0539	-0.479	0.633
ERC	3.817	0.6043	3.777	0.6286	0.0409	0.441	0.660
RNC1	3.616	0.8834	3.298	0.8900	**0.3184**	**2.406**	**0.017**
RNC2	3.576	0.7773	3.415	0.8219	0.1616	1.348	0.179
RNC3	4.000	0.8165	3.702	0.9928	**0.2979**	**2.200**	**0.029**
RNC4	3.581	0.8874	3.202	1.0634	**0.3793**	**2.606**	**0.010**
RNC	3.688	0.6954	3.404	0.8207	**0.2837**	**2.491**	**0.014**
IP1	3.553	0.7793	3.391	0.9716	0.1616	1.225	0.222
IP2	3.410	0.8120	3.505	0.8866	-0.0959	-0.741	0.459
IP3	3.388	0.6564	3.409	0.8876	-0.0204	-0.175	0.861
IP4	3.115	1.0190	3.154	1.0102	-0.0385	-0.246	0.806
IP5	3.300	0.8329	3.258	0.9077	0.0419	0.315	0.753
IP	3.368	0.5923	3.341	0.7525	0.0270	0.267	0.790

4.2. Measurement model evaluation

Because all the constructs in the model are reflective, individual item reliability (i.e. indicators' loadings above 0.707), construct reliability (i.e. composite reliability above 0.8), convergent validity (i.e. average variance extracted [AVE] over 0.5, and discriminant validity (i.e. constructs sharing more variance with their own indicators than with other constructs) had to be verified (Table 3 and Table 4). Individual item reliability assesses whether the indicators of each latent variable actually measure that variable. Construct reliability checks the internal consistency of the indicators measuring each latent variable. Convergent validity shows whether each latent variable is linked to its indicators. Discriminant validity checks whether each latent variable measures different phenomena.

Table 3. Measurement model evaluation, part I (individual item reliability, construct reliability and convergent validity) (1 of 2)

	Models	
Constructs and measures	High-tech firms	Low-tech firms
Size	ρ_c = 1.000	ρ_c = 1.000
(control variable)	AVE = 1.000	AVE = 1.000
	Loadings	Loadings
Natural logarithm of the number of employees.	1.0000	1.0000
Industry	ρ_c = 1.000	ρ_c = 1.000
(control variable)	AVE = 1.000	AVE = 1.000
	Loadings	Loadings
Manufacturing firm = 1; Service firm = 0.	1.0000	1.0000
Human capital	ρ_c = 0.801	ρ_c = 0.845
(control variable, reflective)	AVE = 0.575	AVE = 0.645
	Loadings	Loadings
HC1 Our employees are highly skilled at their jobs.	0.6814	0.7934
HC2 Our employees are highly motivated in their job.	0.8247	0.8489
HC3 Our employees have a high level of expertise.	0.7614	0.7652
Structural capital	ρ_c = 0.888	ρ_c = 0.882
(reflective)	AVE = 0.726	AVE = 0.716
	Loadings	Loadings
SC1 Our company has efficient and relevant information systems to support business operations.	0.7767	0.7350
SC2 Our company has a great deal of useful knowledge in documents and databases.	0.8591	0.9187
SC3 Existing documents and solutions are easily accessible.	0.9150	0.8744
Internal relational capital	ρ_c = 0.923	ρ_c = 0.899
(reflective)	AVE = 0.799	AVE = 0.749
	Loadings	Loadings
IRC1 Different units and functions within our company – such as R&D, marketing and production – understand each other well.	0.8879	0.7978
IRC2 Our employees frequently collaborate to solve problems.	0.8682	0.8985
IRC3 Internal cooperation in our company runs smoothly.	0.9245	0.8960
External relational capital	ρ_c = 0.884	ρ_c = 0.892
(reflective)	AVE = 0.718	AVE = 0.735
	Loadings	Loadings
ERC1 Our company and its external stakeholders – such as customers, suppliers and partners – understand each other well.	0.8215	0.8506
ERC2 Our company and its external stakeholders frequently collaborate to solve problems.	0.8579	0.8219
ERC3 Cooperation between our company and its external stakeholders runs smoothly.	0.8625	0.8972

Table 3. Measurement model evaluation, part I (individual item reliability, construct reliability and convergent validity) (2 of 2)

Constructs and measures	Models	
	High-tech firms	Low-tech firms
Renewal capital (reflective)	ρ_c = 0.892 AVE = 0.674 Loadings	ρ_c = 0.926 AVE = 0.757 Loadings
RNC1 Our company has acquired a great deal of new and important knowledge.	0.7688	0.8685
RNC2 Our employees have acquired many important skills and abilities.	0.8373	0.8214
RNC3 Our company can be described as a learning organisation.	0.8679	0.9305
RNC4 The operations of our company can be described as creative and inventive.	0.8078	0.8561
Innovation performance (reflective)	ρ_c = 0.835 AVE = 0.504	ρ_c = 0.900 AVE = 0.644
Compared to its competitors, how successfully has your company managed to create innovations in the following areas over the last year?	Loadings	Loadings
IP1 Products and services for customers	0.7147	0.8088
IP2 Production methods and processes	0.6825	0.8478
IP3 Management practices	0.6495	0.8191
IP4 Marketing practices	0.7417	0.7755
IP5 Business models	0.7554	0.7573

Notes: ρc: composite reliability; AVE: average variance extracted.

Table 4. Measurement model evaluation, part II (discriminant validity)

		1	2	3	4	5	6	7	8
	High-tech firms								
1.	**Size**	**(1.000)**							
2.	**Industry**	**0.323**	**(1.000)**						
3.	**HC**	**-0.064**	**-0.211**	**(0.758)**					
4.	**SC**	**-0.186**	**-0.140**	**0.427**	**(0.852)**				
5.	**IRC**	**0.027**	**-0.112**	**0.463**	**0.488**	**(0.894)**			
6.	**ERC**	**-0.066**	**-0.233**	**0.446**	**0.290**	**0.397**	**(0.847)**		
7.	**RNC**	**-0.066**	**-0.208**	**0.501**	**0.480**	**0.475**	**0.489**	**(0.821)**	
8.	**Innovation performance**	**-0.237**	**-0.124**	**0.374**	**0.271**	**0.243**	**0.368**	**0.438**	**(0.710)**
	Low-tech firms								
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
1.	**Size**	**(1.000)**							
2.	**Industry**	**-0.015**	**(1.000)**						
3.	**HC**	**0.032**	**-0.055**	**(0.803)**					
4.	**SC**	**0.061**	**0.142**	**0.493**	**(0.846)**				
5.	**IRC**	**-0.067**	**0.059**	**0.567**	**0.527**	**(0.865)**			
6.	**ERC**	**0.017**	**0.055**	**0.401**	**0.323**	**0.313**	**(0.857)**		
7.	**RNC**	**0.065**	**0.088**	**0.415**	**0.578**	**0.531**	**0.387**	**(0.870)**	
8.	**Innovation performance**	**0.081**	**0.053**	**0.200**	**0.475**	**0.233**	**0.378**	**0.637**	**(0.802)**

Notes: Diagonal elements (values in parentheses) are the square root of the variance shared between the constructs and their measures, relative to the amount due to measurement error (AVE). Off-diagonal elements are the correlations among constructs. For discriminant validity, diagonal elements should be larger than off-diagonal elements.

As seen in Table 3 and Table 4, all of the parameters have adequate levels, except for the loadings of three indicators in high-tech firms: HC1, IP2 and IP3, whose values are 0.6814, 0.6825 and 0.6495, respectively. Because they are very close to the established acceptable limit for individual item reliability—that is, 0.707—they were all retained in the model.

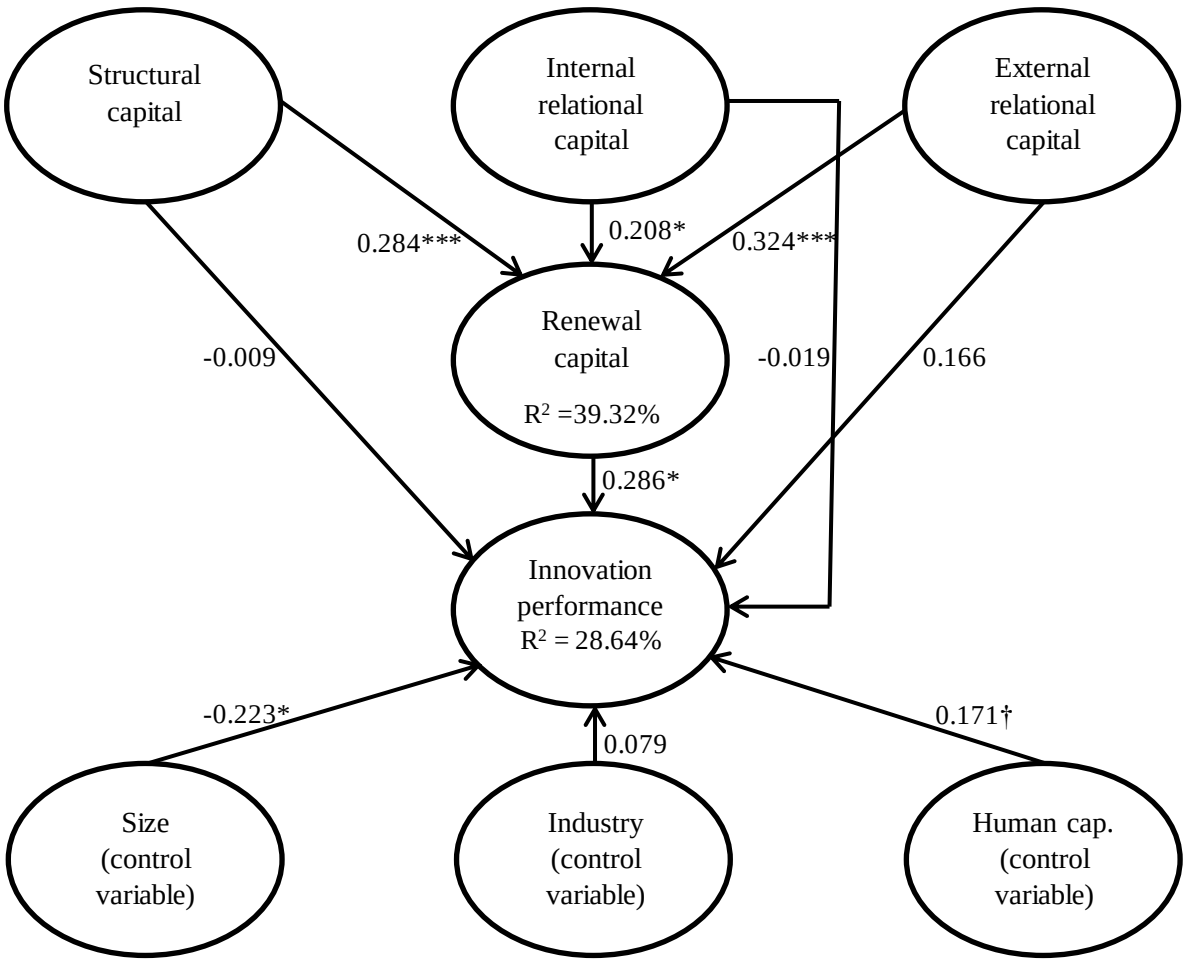
4.3. Structural model evaluation

Table 5 and Figure 2 and Figure 3 show the extent to which hypotheses 1 through 5 are satisfied in both high- and low-tech firms, as well as the amount of variance explained (R^2) for each endogenous construct (i.e. RNC and innovation performance).

Table 5. Structural model evaluation

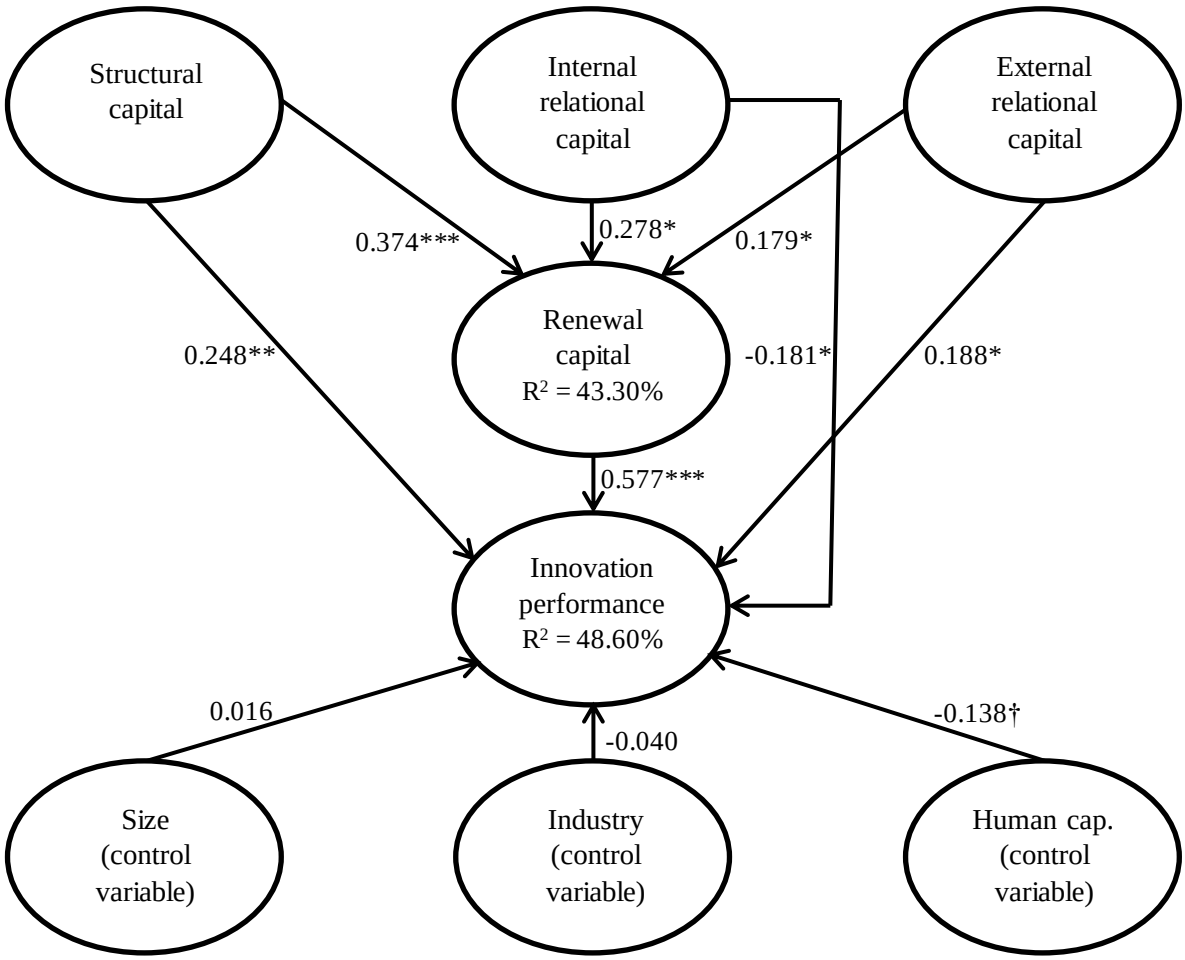
		Exogenous constructs							
		Size	**Industry**	**HC**	**SC**	**IRC**	**ERC**	**RNC**	**R^2**
RNC in HT	**Beta**				**0.284**	**0.208**	**0.324**		**39.32%**
	t-value				**3.1993**	**1.8368**	**3.5453**		
	p-value				**0.0007**	**0.0334**	**0.0002**		
RNC in LT	**Beta**				**0.374**	**0.278**	**0.179**		**43.30%**
	t-value				**3.5994**	**1.8749**	**1.8491**		
	p-value				**0.0002**	**0.0307**	**0.0325**		
IP in HT	**Beta**	**-0.223**	0.079	**0.171**	-0.009	-0.019	0.166	**0.286**	**28.64%**
	t-value	**1.8162**	0.8271	**1.3716**	0.0544	0.1355	1.1844	**1.9963**	
	p-value	**0.0350**	0.2043	**0.0854**	0.4783	0.4461	0.1184	**0.0232**	
IP in LT	**Beta**	0.016	-0.040	**-0.138**	**0.248**	**-0.181**	**0.188**	**0.577**	**48.60%**
	t-value	0.2461	0.4691	**1.3127**	**2.3542**	**1.6559**	**1.7632**	**5.9854**	
	p-value	0.4029	0.3196	**0.0949**	**0.0095**	**0.0492**	**0.0392**	**0.0000**	

Notes: Based on t_{499}, one-tailed test.



Notes: ***p<0.001, **p<0.01, *p<0.05, †p<0.1 (based on t_{499}, one-tailed test).

Figure 2. Structural model evaluation in high-tech firms



Notes: ***p<0.001, **p<0.01, *p<0.05, †p<0.1 (based on t_{499}, one-tailed test).

Figure 3. Structural model evaluation in low-tech firms

As seen in Table 5, SC, IRC and ERC positively and significantly affect the organisation's capability to renew its knowledge-base (RNC). This is the case in both high- and low-tech firms. Hence, hypotheses H1 and H2 are fully satisfied. Similarly, RNC exerts a positive and statistically significant influence on innovation performance in both groups of companies. Therefore, hypothesis H3 is also accepted.

Regarding the direct influence of SC and RC on innovation performance, the following finding was observed. In high-tech firms, the direct influence of these IC components on innovation performance is not statistically significant. Hence, hypotheses H4i, H5ai and H5bi are rejected. Conversely, in low-tech companies, SC and ERC positively and significantly affect innovation performance. Thus, hypotheses H4ii and H5bii are accepted.

The IRC situation within low-tech firms is especially noteworthy. In the presence of the mediator (RNC), the direct influence of IRC on innovation performance becomes negative and statistically significant. Therefore, hypothesis H5aii is rejected. Moreover, the obtained result indicates a potential case of competitive or inconsistent mediation.

For the mediation effects to be definitively confirmed (so far, the positive and statistically significant influences of SC and RC on RNC and of the latter on innovation performance are

suggestive), the degree of significance of the indirect effects (i.e. the result of multiplying the path coefficient linking each exogenous variable with the mediator by the path coefficient, which links the mediator to the dependent variable) were tested using bootstrapping techniques. Table 6 and Table 7 show the results that were obtained.

Table 6. Indirect effects of SC, IRC and ERC on IP through RNC in high-tech firms

	Indirect effect of SC on IP through RNC	Indirect effect of IRC on IP through RNC	Indirect effect of ERC on IP through RNC
Indirect effect	0.081	0.059	0.093
t-value	1.8227	1.1484	1.6949
p-value	0.0689	0.2514	0.0907
Mediation	Yes	No	Yes
Direct effect sign.	Not significant	Not significant	Not significant
Type of mediation	Full	NA	Full

Notes: Based on t_{499}, two-tailed test.

Table 7. Indirect effects of SC, IRC and ERC on IP through RNC in low-tech firms

	Indirect effect of SC on IP through RNC	Indirect effect of IRC on IP through RNC	Indirect effect of ERC on IP through RNC
Indirect effect	0.216	0.160	0.103
t-value	2.8725	1.7818	1.7461
p-value	0.0042	0.0754	0.0814
Mediation	Yes	Yes	Yes
Direct effect sign.	Positive and significant	Negative and significant	Positive and significant
Type of mediation	Partial	Inconsistent	Partial

Notes: Based on t_{499}, two-tailed test.

As seen in Table 6, in the case of high-tech firms, all of the indirect effects are statistically significant, except the one involving IRC. Thus, RNC mediates the relationship between SC and innovation performance and between ERC and innovation performance. Because the direct influence of both SC and ERC on innovation performance is not statistically significant, full mediation applies.

In the case of low-tech firms (Table 7), all the indirect effects were found to be statistically relevant. This result definitely confirms the mediation effects. Because the direct influence of SC and ERC on innovation is positive and statistically significant, partial mediation applies. However, because the direct influence of IRC on innovation performance is negative and statistically relevant, inconsistent mediation applies. Consequently, hypothesis H6 is only partly accepted.

Finally, Table 8 shows the results of the multi-group analysis.

Table 8. Multi-group analysis

	Exogenous constructs	Beta (HT)	Beta (LT)	t-value	p-value
RNC	SC	0.284	0.374	-0.6563	0.2560
	IRC	0.208	0.278	-0.3722	0.3550
	ERC	0.324	0.179	1.0625	0.1443
Innovation performance	Size	**-0.223**	**0.016**	**-1.7716**	**0.0385**
	Industry	0.079	-0.04	0.9374	0.1745
	HC	**0.171**	**-0.138**	**1.9162**	**0.0280**
	SC	**-0.009**	**0.248**	**-1.3400**	**0.0904**
	IRC	-0.019	-0.181	0.9247	0.1778
	ERC	0.166	0.188	-0.1269	0.4495
	RNC	**0.286**	**0.577**	**-1.7203**	**0.0430**

Notes: Based on t_{499}, one-tailed test.

In terms of the influence of SC and RC on RNC, even though SC appears to be the most relevant enabler of RNC in low-tech companies (followed by IRC and ERC), and the opposite holds for high-tech firms (i.e. ERC is the most relevant component to foster organisational learning in such companies, followed by SC and IRC), no statistically significant differences were found between these two types of firms. Based on the results presented above, it can be affirmed that both SC (i.e. the result of codification KM strategies) and RC (i.e. the result of personalisation KM strategies) are equally relevant to learning and to renewing a company's knowledge-base in both high- and low-tech firms.

Meanwhile, hypothesis H7 is partly satisfied, as some statistically significant differences arise in the remaining direct influence of certain IC components on innovation. In particular, the direct influence of SC and RNC on innovation performance is significantly greater in low-tech firms than high-tech firms.

Regarding the control variables, size was found to exert a negative influence on innovation in the case of high-tech firms (the smaller the company, the more innovative). In contrast, HC exerts a positive and statistically significant influence on innovation in such firms. In low-tech firms, however, the direct influence of HC on innovation is negative and statistically significant. This surprising result may hide the mediation effect of other IC components in the HC–innovation relationship. When taken in isolation, HC exerts a positive and statistically significant influence on innovation. Given the negative influence that rises to the surface when the other IC components are added, additional post hoc analyses were conducted; these revealed that HC is a key antecedent of SC, RC (both internal and external) and RNC in low-tech firms, and its influence on innovation performance mainly occurs through these components.

Finally, and in terms of the amount of explained variance, it should be noted that RNC is very similar for both high-tech and low-tech firms (39.57% and 42.68%, respectively), while innovation performance is different (26.70% for high-tech firms versus 48.49% for low-tech firms). We will further address this issue in the Discussion section.

5. Discussion

This study analysed the complementary role of SC and RC as the outcomes of codification and personalisation KM strategies in RNC and subsequent innovation in high- and low-tech firms. Even though the extant literature on IC has traditionally omitted RNC, this study demonstrated that RNC can be an important component of IC when fostering innovation performance.

We agree with Kianto *et al.* (2010) that RNC is largely dependent on both the set of knowledge resources accumulated in companies' structures, databases and information systems (SC) and the knowledge embedded in internal and external networks of relationships (IRC and ERC). Firms with strong SC, IRC and ERC present a solid knowledge-base upon which RNC can be successfully developed. Thus, to a large degree, knowledge renewal is determined by the previously developed knowledge resources in the form of codified (SC) and tacit knowledge (IRC and ERC).

Contrary to our expectations, we found no statistically significant differences between high- and low-tech firms in terms of how they learn and renew their knowledge-base (RNC). Because SC and RC result from codification and personalisation strategies, respectively, this study demonstrated that both KM strategies are relevant in high- and low-tech firms. This finding is in accordance with the results reported in existing literature on KM strategies, which argue in favour of combining both strategies instead of eliminating of one of them (Hansen *et al.*, 1999; Storey and Kahn, 2010; Ajith Kumar and Ganesh, 2011). More precisely, Hansen *et al.* (1999) argue that firms must select a primary KM strategy and a secondary KM strategy; 80% of their knowledge should stick to the primary strategy and the remaining 20% should follow the secondary strategy. Alternatively, Storey and Kahn (2010) defend blending both strategies. Irrespective of the specific split into codification and personalisation, the present study has proven that companies take advantage of both strategies; thus, it is important to promote codification in high-tech firms and enhance personal interactions in low-tech companies.

Relevant differences between high- and low-tech companies were found in the way in which IC components affect innovation. In high-tech companies, innovation hinges on RNC rather than on the other IC components that the study considered. In contrast, in low-tech firms, innovation depends on several IC components. This finding reveals the differences that are ingrained in the level of technological sophistication. High-tech firms manage knowledge that should be frequently renewed; thus, the other knowledge entities favour innovation to the extent that they foster the ability to learn and to renovate the firm's knowledge-base. Low-tech companies are not under pressure to constantly renew their knowledge-base, so there is a balance in the influence of IC components on innovation.

In the case of high-tech firms, SC and ERC do not affect innovation directly; they only do so by means of RNC. Along with Hsu and Fang (2009) and Zhang and Lv (2015), the present study reveals that when learning is considered, tacit and codified knowledge foster innovation through knowledge renewal and update. The only exception is IRC, which does not enhance innovation performance either directly or by means of RNC. The increasing complexity embedded in the knowledge that is managed by high-tech firms makes the knowledge exchanged in internal connections between individuals necessary for learning, acquiring new skills and updating knowledge stocks (RNC), but insufficient for innovation.

For low-tech companies, RNC is a partial mediator in the link between both SC and ERC and innovation performance. When enhancing innovation performance, RNC supports the renovation and updating of the codified knowledge that is accumulated in databases and information systems (SC), as well as tacit knowledge from outside of the company (ERC). However, because knowledge renewal is not as frequent in low-tech companies as it is in high-tech companies, both SC and ERC continue to foster innovation directly. In fact, the link between SC and innovation is considerably stronger in low-tech firms than in high-tech companies, confirming the higher relevance of explicit knowledge in the first group of firms (Nelson and Wright, 1992; Rosenbloom, 2014). Surprisingly, the RNC–innovation connection is also considerably greater in low-tech firms in comparison to their high-tech competitors. Although, according to the literature, firms with a lower level of technological sophistication do not renovate their knowledge-bases as frequently as firms with higher levels of technological sophistication (De Carolis, 2014), this

finding suggests that low-tech firms that engage in knowledge renewal more frequently gain advantages when it comes to being successful innovators. Furthermore, contrary to the widespread assumption that internal relations enhance innovation (Carmona-Lavado *et al.*, 2010; Wang and Chen, 2013), the present study revealed the existence of counterproductive internal relationships. Interactions amongst employees promote knowledge-sharing, problem-solving and internal cooperation, which are believed to enhance innovation. However, internal relations that do not have a clear orientation towards learning and renewal seem to be counterproductive for the promotion of innovation. This could be the case for meetings that lead to the excessive and unnecessary repetition of ideas, thus, delaying innovation, or if the negative influence of employees who are reluctant about innovation slows down the process.

The role of control variables amongst both groups of companies also deserves special attention. Size exerts a negative impact on innovation in the high-tech group, as small firms are more agile in making decisions and implementing innovations (Nooteboom, 1994). This is especially relevant for companies with a high level of technological sophistication that tend to manage knowledge that must be frequently renewed (De Carolis, 2014). These firms must bring out new innovations more quickly than their competitors. Concerning HC, the increasing complexity embedded in the knowledge that is present in high-tech companies (Schilling, 2011) makes it especially necessary to have highly-knowledgeable and skilled employees. In low-tech firms, HC does not exert a strong influence on innovation performance; however, because employees' knowledge, skills, abilities and motivation constitute the cornerstone of IC, HC enhances the codification and storage of knowledge (SC), internal relationships amongst individuals (IRC), interactions between company members and external partners (ERC) and the ability to learn and to renew the knowledge-base (RNC). While it seems that HC plays a key role in both types of companies, the specific role differs according to the technological level of the company being analysed.

Finally, and concerning the differences in the amount of variance explained in innovation performance, specific knowledge characteristics related to a firm's technology level seem to play an important role. As previously explained, high-tech firms utilise knowledge that should be frequently renovated, thus making RNC a critical component for survival. Accordingly (and as the descriptive analyses presented in Table 2 indicate), high-tech companies have developed RNC to a larger extent than low-tech firms, and more homogenously (see the lower standard deviations observed for each RNC item in the high-tech companies). Consequently, RNC results in less variation in innovation performance in high-tech companies.

6. Conclusions

Although the relationship between IC and innovation has been clearly demonstrated, the role of RNC as an IC component and the differences ingrained in the technological sophistication of companies deserve further scrutiny. Likewise, scant attention in the literature has been paid to the interactions between KM strategies and IC components. To address these gaps, the present study explored the complementary role of SC and RC as codification and personalisation outcomes in enhancing RNC and innovation performance in companies with different levels of technological sophistication.

The results obtained offer four key novelties that will be addressed further in this section: (1) it demonstrates the relevance of RNC as an IC component; (2) it presents a novel understanding about the interactions between IC components when influencing innovation performance; (3) it extends the debate about the link between KM strategies and IC components (knowledge resources); and (4) it proves how the IC–innovation linkage differs depending on the technological level of the innovating organisation.

6.1 Implications for researchers and practitioners

From an academic perspective, this paper contributes to the literature about KM and IC. Firstly, this paper enlarges the literature on IC by analysing the role of RNC amongst other traditional IC components and by studying the IC–innovation linkage, including a new combination of IC components. Based on these results, it seems RNC is an especially important knowledge resource for innovation. Therefore, RNC should be included in future studies that aim to understand innovation performance from a knowledge-based perspective. This contribution could seem to be repetitive because the concept of renewal has been discussed in the traditional IC literature (e.g. Edvinsson and Malone, 1997; Roos *et al.*, 1997; Sveiby, 1997). However, because the literature on IC has given short shrift to the renewal capability of organisations, this finding becomes crucial in the IC field. In addition, the present paper adds to the existing debate on how KM strategies and knowledge resources (IC components) are connected (Kianto *et al.*, 2014; Handzic and Durmic, 2015; Khadir-Poggi and Keating, 2015; Marzo and Scarpino, 2016; Rossi *et al.*, 2016; Zaragoza-Sáez *et al.*, 2016). Whilst the existing literature has traditionally analysed KM strategies and IC as two separate fields of research (Kianto *et al.*, 2014), the present study tries to connect KM as the dynamic approach to knowledge and IC as the static approach to knowledge (Kianto, 2007). Furthermore, this research contributes to the understanding of how knowledge and its management differ in high- and low-tech firms. Very few previous studies have considered technological sophistication as a contingency variable; by proving its relevance, this project supports a new stream of literature in which the contingencies affecting the IC–innovation linkage are scrutinised.

For business practitioners, this study supports managers in the daunting task of innovating in a resource-constrained environment. By considering the technological level as a contingency variable, this study has revealed the need to adopt a targeted approach to IC management. In both high- or low-tech companies, business managers should adapt their efforts to strengthen IC components to the way in which those components interact when promoting innovation.

In high- and low-tech companies, because RNC is enhanced by other IC components, if resources are limited, it may be advisable to invest in other IC components first because they would, by extension, increase RNC. Managers might also use the company's strategic plans to identify critical areas for the firm's future success and define the combination of knowledge and skills that employees should have. This might help managers know to what extent and in which areas knowledge must be renovated.

To improve SC, employees might be asked to share their opinions on how to improve databases, technologies and other structural support issues in the organisation; after all, their importance to a firm's performance hinges on how they enhance employees' work activities. Being up to date on new technological developments might also support the improvement of SC. This is especially relevant for low-tech companies, as SC plays a more important role in those firms than in high-tech firms.

In terms of IRC, development actions should be directed towards intra-firm relationships that promote learning and knowledge renewal. This requires firms to recognise that not all relations fulfil this goal. Indeed, as IRC could negatively affect innovation in low-tech firms, managers in these companies should be alert to formal and informal interactions among employees that could have this negative impact.

Finally, ERC could be promoted by adopting social media to connect with external actors because they could provide relevant information to promote renewal and innovation in the firm. Benchmarking how competitors deal with stakeholders might also be a source of valuable ideas.

The strong connection between ERC and RNC in high-tech industries makes this implication particularly important in this group of companies.

6.2 Limitations and future research

As with all studies, this one is subject to several limitations, some of which may give rise to fruitful research avenues in the future. Firstly, the sample only consisted of Spanish firms. Because there is some evidence that knowledge-related issues differ across countries (Li *et al.*, 2014; Sáenz *et al.*, 2017), it is quite possible that the relationships between the study variables may be different in other geographical and cultural contexts. Thus, future studies could test the same hypotheses in other locations and complement research works that have compared the structure and development of IC stocks in several geographical places (Inkinen *et al.*, 2017; Sáenz *et al.*, 2017).

Furthermore, data on IC components and innovation performance were acquired from the same respondent in each company, leading to the potential problem of common method bias. A Harman one-factor test was conducted, and the satisfactory results suggested that bias did not have a serious confounding effect on the results. Nevertheless, an objective external measure for innovation performance would be a better option. In addition, this is a cross-sectional study that captures data at a single point in time. Longitudinal approaches to this issue could provide valuable insights about the interactions between IC and innovation performance.

The present study also addressed four IC components to the neglect of other possibilities, such as entrepreneurial capital, information capital and technological capital (cf. Inkinen, 2015). These additional components could be applied in future studies to complement and add to the model tested in this paper. The industry life cycle is another variable that could enrich future studies. Being in various stages of the life cycle (introduction, growth, maturity and decline) could possibly affect the relationship between IC and innovation. For example, firms in the introduction phase tend to enhance SC less than companies in the maturity phase because they lack experience that helps them codify knowledge.

Finally, since HC is an antecedent of SC, IRC, ERC and RNC in low-tech firms, it could be interesting to delve deeper into the role of HC as a factor promoting the other IC components. Moreover, the present study's results might be affected by the fact that a large proportion of the respondents were human resources managers in their respective firms. It is recommended that future studies attempt to balance the profile of the respondents taking part in the survey.

Appendix

List of Acronyms

IC: Intellectual capital

HC: Human capital

SC: Structural capital

RC: Relational capital

IRC: Internal relational capital

ERC: External relational capital

RNC: Renewal capital

KM: Knowledge management

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