

## **Assessing Knowledge Assets in Technology-Intensive Firms: Proposing a Model of Intellectual Capital**

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### **Abstract**

Knowledge assets are key organizational factors responsible for gaining a sustained competitive advantage in the new knowledge economy characterized by high degrees of environmental turbulence, complexity, and dynamism. Although the scientific and professional literature has provided numerous proposals for measuring a firm's knowledge stock or intellectual capital, further research is still needed because empirically supported models for the classification and measurement of a firm's intellectual capital, adapted to different contexts, are not very common. To fill this gap, a model has been developed in order to analyze the nature and measurement of intellectual capital blocks in technology-intensive firms.

*Keywords:* Intellectual capital, human capital, organizational capital, technological capital, relational capital, technology-intensive firms

*JEL Classification code:* O32

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Due to the increased turbulence, dynamism, and complexity of the current business environment, knowledge or intellectual capital management has become a key managerial task which enables the transformation of data into information in order to facilitate organizational learning and knowledge creation. The theorists' starting point is the importance of identifying, measuring, and managing information, knowledge, and learning (Johannessen, Olsen, & Olaisen, 2005) because knowledge and information assets are key elements for creating and maintaining a firm's competitive advantage and superior performance (Edvinsson & Malone, 1997; Teece, 1998). Numerous theoretical proposals about the measurement of a firm's intellectual capital have emerged (Brooking, 1996; Bueno, 1998; Centro de Investigaciones sobre la Sociedad del Conocimiento (CIC), 2003; Edvinsson & Malone, 1997), highlighting the fact that intellectual capital is a complex phenomenon which requires a comprehensive theoretical and empirical analysis (Cabrita & Bontis, 2008).

Despite the great value of these contributions, much remains to be done to adapt these theoretical and empirical models to different industry contexts and to new social and economic trends. Model-tailoring is particularly needed for knowledge-intensive industries such as high and medium-high technology manufacturing firms for which information, knowledge, and learning are key production factors, and empirically supported models are scarce (Lim & Dallimore, 2004). In this sector, empirical evidence for the classification and measurement of intellectual capital is still needed.

Many researchers distinguish three main components of intellectual capital: human capital, structural capital, and relational capital. However, the prominent role technological knowledge plays in technology-intensive firms indicates an alternative classification which divides structural capital into organizational capital and technological capital. This classification appears to be better adapted to this kind of firms.

The purpose of this paper is to provide a configurative definition of intellectual capital which is adapted to technology-intensive firms. The term intellectual capital incorporates concepts which have been widely treated in academic literature for more than two decades. Hence, the first section shows an analysis of the concept and the main components, multidimensional in nature, of intellectual capital. Particular emphasis is placed on the distinction between technological capital and organizational capital, in contrast with other studies in which technological capital is not explicitly taken into account. In the second section, in order to enrich the scarce literature with empirical evidence regarding the components and dimensions of intellectual capital (Martinez-Torres, 2006), a research method and a measurement scale are provided. This section shows the measurement tools used for capturing intellectual capital and characteristics of the chosen sample of firms used for empirical testing. The final section indicates the different, empirically obtained, components of human, organizational, technological, and relational capital and the main implications for future research and management practice that derive from these findings.

### **Intellectual Capital: Concept and Main Components**

Scholars and practitioners have long recognized that economic wealth comes from knowledge assets, in other words, intellectual capital and its useful application (Teece, 1998). Only recently, however, has specific attention been placed on the management of a firm's intellectual capital in order to face the increased complexity and turbulence of the business environment. Firms dealing with knowledge management issues face numerous difficulties arising from the identification, measurement, and strategic assessment of their intellectual capital. Intellectual capital models thus become very important because they help both to understand the nature of knowledge assets and to carry out their measurement.

The term intellectual capital is used as a synonym for intangible or knowledge assets (Stewart, 1998). The word *capital* indicates its economic roots: in 1969, the economist Galbraith described it as either a process of value creation or as a bundle of assets. Bueno (1998) defined intellectual capital as "basic competences, based on knowledge and information, of intangible character that allow creating and maintaining a competitive advantage" (p. 221), thus showing the link between intellectual capital and the resource-based view of a firm. Reed, Lubatkin, and Srinivasan (2006) argued that an intellectual capital-based view of the firm was a true and pragmatic theory that enables the empirical test of the resource-based view.

The different types of intellectual capital represent different types of intangible resources and capabilities. Many scholars have suggested that in spite of their strategic nature, all these assets are not equally valuable for the firm (Aaker, 1989; Hall, 1992, 1993; Itami & Roehl, 1987; Prahalad & Hamel, 1990). Thus, as the required intangible factors will depend on the industry in which a firm operates, in terms of strategic management, a clear identification of the main components of intellectual capital is required in order to make the right decisions about the development, protection, or maintenance of the most valuable intangible assets.

Scholars have provided different frameworks for classifying the components of intellectual capital and for establishing indicators for intellectual capital measurement. Most scholars have agreed on the identification of three main components: (a) human capital, (b) structural capital, and (c) customer or relational capital (Bontis, 1996; Cabrita & Bontis, 2008; Carson, Ranzijn, Winefield, & Marsden, 2004; Edvinsson & Malone, 1997; Kaplan & Norton, 1992; Kong, 2008; Moon & Kym, 2006; Saint-Onge, 1996; Stewart, 1998; Sveiby, 1997; Wu, Chang, & Chen, 2008). However, the heterogeneous nature of the concept has led to the identification of different components: human, structural, technological, organizational, relational, or social capital. This phenomenon shows that theoretical proposals about intellectual capital are becoming more complex and detailed every day. This diversity encourages analytical reflection among managers and chief knowledge officers, but it can also appear as too extensive a proliferation of criteria and categories of intangible assets.

Therefore, given the importance of technological knowledge within high and medium-high technology industries, which are strongly focused on intangible factors (Leitner, 2005) and specifically on research and development (R&D) intensity (Huergo, 2006), the purpose of this paper is to focus on technological capital. Scholars have divided structural capital into organizational and technological capital (Brooking, 1996; Carlucci & Schiuma, 2007; Edvinsson & Sullivan, 1996; Hayton, 2005; Sveiby, 1997) and argued that both components

are uneven in nature, have different strategic implications (CIC, 2001), and require different strategies for their accumulation and exploitation (Tseng & Goo, 2005). While organizational capital is referred to as social or administrative behavior (CIC, 2003), technological capital is related to the technological efforts and developments within the operations area.

The term intellectual capital is thus understood as composed of four components: human capital, organizational capital, technological capital, and relational capital. Most scholars understand human capital as those capabilities owned by people that facilitate learning and future knowledge creation. Issues such as education, training, learning, leadership, the ability to solve problems, managerial capacity, motivation, or talent are good examples of human capital (Brooking, 1996; Reed et al., 2006; Roos & Roos, 1997). There is consensus in the identification of most of the elements that make up human capital, but some researchers have argued for more debatable elements. For instance, Edvinsson and Sullivan (1996) included the employees' general know-how which can be considered as structural capital because it receives knowledge from all employees and therefore belongs to the firm. Edvinsson and Malone (1997) included in human capital a firm's values, culture, and philosophy as aspects that make possible the firm's operations (Brooking, 1996) and that remain in the firm when employees go home.

In contrast, the term structural capital has been defined in a number of ways. Given the purpose of this paper, only those contributions that refer to the technological aspects of the term are highlighted. A number of scholars have made a distinction between the implicit or explicit consideration of technological issues (Brooking, 1996; Bueno, 1998; Bueno & Azúa, 1997; Carlucci & Schiuma, 2007; CIC, 2003; Pike, Göran, & Marr, 2005). Other scholars have considered the technological aspects as separate from other aspects (Hayton, 2005), and sometimes the technological aspects are mixed with the firm's methods or know-how (Edvinsson & Sullivan, 1996; Sveiby, 1997) or are not considered at all (Steward, 1998).

Organizational capital refers to all the aspects included in structural capital, such as methods, processes, or structures, except those regarding technological efforts and developments within the production area, which are included in technological capital. Swart (2006) asserted that organizational capital may be understood as a vehicle in order to obtain structural capital. Organizational capital is a wide concept related to organizational design; that is, intrinsic knowledge owned by a firm, whereby a firm's culture, philosophy, organization chart, databases, process manuals, decision-making processes, or routines are taken into account. Knowledge collected in organizational capital is collective and belonging to the firm, regardless of employees.

We disagree with the classification of some elements into the category of organizational capital. For instance, a few scholars have seen customer relationships, cooperation, or business reputation as organizational capital (Edvinsson & Sullivan, 1996; Pike et al., 2005; Roos & Roos, 1997). We believe that these aspects are part of relational capital because they refer to knowledge embedded in networks at institutional level. Edvinsson and Malone (1997) and Pike et al. (2005) considered the brand as organizational capital; we also believe the brand should be included in relational capital because it is a commercial aspect by nature and, therefore, it is linked to customers. Similarly, Pike et al. (2005) have classified intellectual property as organizational capital; we view intellectual property as part of technological capital because it involves a registered technical knowledge owned by the firm.

Most intellectual capital studies have indicated technological capital as being part of structural capital. For example, Bueno (1998), CIC (2003), or Ordóñez (2004) presented intellectual capital within their structural capital breakdowns. Bontis (1998) took into account technological aspects when explaining the meaning of structural capital. Brooking (1996), Edvinsson and Sullivan (1996), and Hayton (2005) also examined separately technological issues, and other scholars, who did not explicitly consider technological capital, included technological aspects such as patents, intellectual property, or trademark within their definitions of structural or organizational capital (Bueno & Azúa, 1997; Edvinsson & Malone, 1997; Pike et al., 2005; Sveiby, 1997; Youndt, Subramaniam, & Snell, 2004). Similarly, Roos and Roos (1997) split organizational capital into business process capital and business renewal and development capital, understanding the latter as technological capital. These scholars also included sales and marketing or cooperation forms as part of organizational capital; we consider that these aspects are related to relational capital because they refer to external networks and contacts with clients, suppliers, or allies.

Finally, in line with Acedo, Barroso, and Galán (2006) who pointed out that a stream of the resource-based view referred to relationships and networks among firms because of their importance in the current environment, the growing relevance of inter-organizational networks needs to be highlighted. In general terms, relational capital represents internal and external linkages, interactions, and ties or networks, and most

authors have referred to external agents such as clients, suppliers, institutions, shareholders, and so on. For instance, Bontis (1998) asserted that “the essence of customer capital is knowledge embedded in relationships external to the firm” (p. 69), in which Bontis included all types of agents apart from clients. Kong (2008) stated that “relational capital characterizes an organization’s formal and informal relations with its external stakeholders and the perceptions that they hold about the organization, as well as the exchange of knowledge between the organization and its external stakeholders” (p. 291). Kong, following Hayton (2005), considered stakeholders’ perceptions about a firm and included the firm’s reputation in the concept of relational capital. Some authors have mixed relationships among people and relationships at institutional level (Bueno, 1998; Carlucci & Schiuma, 2007; Reed et al., 2006; Subramaniam & Youndt, 2005; Youndt et al., 2004); we believe that these should be considered independently.

In this study, the components of intellectual capital are the following:

- Human capital refers to knowledge possessed by employees and their ability to generate it, which is useful for the firm; this type of knowledge includes values, attitudes, aptitudes, and know-how (Edvinsson & Sullivan, 1996; Subramaniam & Youndt, 2005).
- Organizational capital refers to institutionalized knowledge and organizational mechanisms designed to integrate and transfer knowledge throughout the organization; included are values, norms, climate, culture, and managerial commitment or decision making-processes which make running a firm possible (Brooking, 1996; Hsu & Fang, 2009). While organizational capital includes a wide range of institutional knowledge, the focus of the analysis presented in this paper is on the issues relevant to technology-intensive firms, most of which relate to innovation.
- Technological capital is the organizational knowledge related to the creation or improvement of goods and services and to productive processes; it includes internal and external R&D efforts or technological knowledge stock such as patents (Brooking, 1996; CIC, 2003; Hayton, 2005).
- Relational capital is the knowledge generated with other agents in the context of institutional relationships and makes reference to the value of firms’ external relationships (customers, suppliers, allies, etc.) and reputation (CIC, 2003; Hayton, 2005; Hsu & Fang, 2009; Reed et al., 2006).

The aim of the analysis is to develop more specific measure scales than the general ones used by Reed et al. (2006), Subramaniam and Youndt (2005), and Youndt et al. (2004) who did not distinguish between organizational and technological capital or consider personal networks independently from institutional relationships, as they took into account three intellectual capital components only. The remainder of this paper is focused on the empirical analysis of the intellectual capital components according to the classification presented above. More specifically, the analysis indicates the main components or building blocks of an intellectual capital balance sheet for technology-intensive firms.

## **Methodology**

The model was empirically tested through a survey carried out in technology-intensive firms located in Spain from January to June 2009. The selection of industries was guided by the necessity of using a homogeneous sample of firms which share strategic factor markets (Rouse & Daellenbach, 1999) and by the importance of intellectual capital in this type of industry (Johnson, Neave, & Pazderka, 2002).

From a population of 1270 firms, representatives of 251 firms took part in the survey; the response rate was thus 19.76%. According to Koberg, Detienne, and Heppard (2003), response rates range from 14% to 34% when questionnaires are sent to chief executive officers (CEOs) because top managers have relatively less discretionary time to devote to completing questionnaires. Koberg et al. also asserted that information about the organizational characteristics of firms provided by one top manager informant is valid when survey instruments are well-designed and executed. Table 1 shows a general description of the research methodology.

Table 1  
*Research Methodology*

Population	1270 high and medium-high technology manufacturing firms (> 50 employees)
Sample size	251 firms
Respondents	Senior managers
Country	Spain
CNAE-93 codes	24, 29, 30, 31, 32, 33, 34, 35
Data collection method	Telephone
Data collection duration	From January 2009 to June 2009
Statistical software	SPSS 17.0 AMOS 7.0

The questionnaire employed for the survey included 38 items intended to measure different aspects of intellectual capital according to the four constructs outlined above:

- 9 items were used to assess human capital (HC), based on the measures proposed by Carmeli and Tishler (2004); Chen, Zhu, and Yuan (2004); Huselid (1995); Moon and Kym (2006); Reed et al. (2006); Snell and Dean (1992); Subramaniam and Youndt (2005); Wu et al. (2008); and Youndt et al. (2004);
- 9 items were used to assess organizational capital (OC), based on Carmeli and Tishler (2004), Chen et al. (2004), Moon and Kym (2006), Prajogo and Ahmed (2006), Subramaniam and Youndt (2005), and Youndt et al. (2004);
- 8 items were used to assess technological capital (TC), based on Alegre-Vidal, Lapiedra-Alcami, and Chiva-Gomez (2004), Chen et al. (2004), Hayton (2005), Huergo (2006), Moon and Kym (2006), Nieto and Quevedo (2005), Subramaniam and Youndt (2005), Tippins and Sohi (2003), Tseng and Goo (2005), Youndt et al. (2004); and
- 12 items were used to assess relational capital (RC), based on Carmeli and Tishler (2004), Chen et al. (2004), Dollinger, Golden, and Saxton (1997), Kotabe, Martin, and Domoto (2003), Nieto and Quevedo (2005), Reed et al. (2006), Subramaniam and Youndt (2005), Tippins and Sohi (2003), and Youndt et al. (2004).

The representatives had to assess their firm's intellectual capital on a 7-point Likert-type scale ranging from total agreement to total disagreement regarding the statements shown in the questionnaire. The 38 items listed were taken from general insights about the predefined components of intellectual capital taken into account (see Table 2).

Table 2  
*Questionnaire Items*

HC1: My company allocates resources (money, time, etc.) to employee training to a higher extent than my competitors do.
HC2: In my company, the percentage of people who receive training is higher than in my competitors'.
HC3: In my company, the percentage of people with higher degrees (bachelor's, engineer, masters, etc.) is higher than in my competitors'.
HC4: In my company, the percentage of jobs filled by means of an internal promotion is higher than in my competitors'.
HC5: Our employees have adequate and appropriate experience to carry out their duties satisfactorily.
HC6: Our employees possess abilities that are widely considered the best in our industry.
HC7: Our employees develop new ideas and knowledge.
HC8: Generally speaking, our employees are satisfied in the company.
HC9: Our employees possess a high sense of responsibility with the company.
OC1: My company encourages creativity, innovation, and/or new ideas development.
OC2: In my company, there is a common system of values, beliefs, and objectives directed to new ideas development and innovation.
OC3: My company promotes experimentation and innovation as ways to enhance processes.
OC4: Often, managers involve their employees in important decision-making processes.
OC5: In my company, managers support and lead the innovation process.
OC6: Managers share similar beliefs about the future management of this firm.
OC7: Much of the firm's knowledge relating to processes, systems, and structures is contained in databases, the intranet, electronic files, etc.

- OC8: My company uses CITs that allow learning past situations and improving employees learning and experience.  
 OC9: Preferably, my company uses CITs for communication, coordination, and information distribution.  
 TC1: In my company, the average percentage of R&D employees is one of the highest in the industry.  
 TC2: In my company, the average R&D costs with respect to sales are among the highest in the industry.  
 TC3: My company has a formalized R&D department.  
 TC4: In my company, the average costs of purchasing technology and/or licences are among the highest in the industry.  
 TC5: In my company, the average contracted technical assistance is among the highest in the industry.  
 TC6: The level of legally non-protected technological knowledge base and/or patents is among the highest in the industry.  
 TC7: The usefulness of legally non-protected technological knowledge base and/or patents is one of highest in the industry.  
 TC8: My company uses patents in order to accumulate knowledge.  
 RC1: We obtain much of our valuable information on the market needs and tendencies from our customers' portfolio.  
 RC2: Our employees work jointly with customers in order to develop solutions.  
 RC3: The customer base of my company is among the best in our industry.  
 RC4: Our employees work jointly with suppliers in order to develop solutions.  
 RC5: In the last years, my company has been improving the quality and design of products and processes through relationships with our suppliers.  
 RC6: The supplier base of my company is among the best in our industry.  
 RC7: Our employees work jointly with allies in order to develop solutions.  
 RC8: In the last years, my company has been improving the quality and design of products and processes through relationships with our allies.  
 RC9: The allies base of my company is among the best in our industry.  
 RC10: My company's reputation with respect to products quality is among the best in our industry.  
 RC11: My company's managerial reputation is among the best in the industry.  
 RC12: My company's financial reputation of my company is among the best in the industry.

## Results

First, exploratory factor analyses were carried out in order to identify the factors or latent phenomena revealed in the data about human, organizational, technological, and relational capital provided by the study participants. To decide whether factor analysis is an appropriate technique in cases like these, several preliminary tests are needed: the Bartlett's test and the Kaiser-Meyer-Olkin index. Once the underlying factors were identified, confirmatory factor analyses were carried out in order to refine and validate the measurement model.

### Human Capital

Table 3 shows the results of the tests which indicated that it was advisable to perform the factor analysis, rejecting the null hypothesis that the correlation matrix is an identity matrix as there are several correlations among the considered variables. Moreover, the KMO index is above 0.7, so it can be considered acceptable for exploratory studies, and the factor analysis becomes appropriate.

Table 3  
*Exploratory Factor Analysis for Human Capital*

Items	E&T	Mot	E&A
HC2: Training inside the firm	0.888		
HC1: Employed resources in training activities	0.857		
HC3: Employees with university degree	0.670		
HC9: Use of internal promotion	0.599		
HC8: Commitment and responsibility		0.832	
HC7: Employee satisfaction index		0.804	
HC4: Employee experience			0.843
HC5: Employee valuable abilities			0.741
HC6: Development of new ideas and knowledge		0.479	0.481
% of Standard deviation	27.847	20.483	18.838
Accumulated %	27.847	48.330	67.168

Note. Kaiser-Meyer-Olkin Index (KMO) = 0.802; Bartlett's Test (Chi-square, gf) = 844.646 (36).

The factor analysis indicated that there were three components of human capital, jointly accounting for almost 67% of the total variance. The first component was labeled education and training (E&T). The four items included in this component account for almost 28% of the total human capital of a firm. The element that better characterizes this component is training inside the firm. Another element, employed resources in training activities, also shows an important factorial weight.

The second component accounts for 20% of the human capital of the firm and was labeled motivation (Mot). It includes two elements: commitment and responsibility and employee satisfaction index. The third component refers to the experience and abilities (E&A) of the firm’s employees and accounts for almost 19% of the firm’s human capital. Figure 1 shows the three main factors that make up human capital.

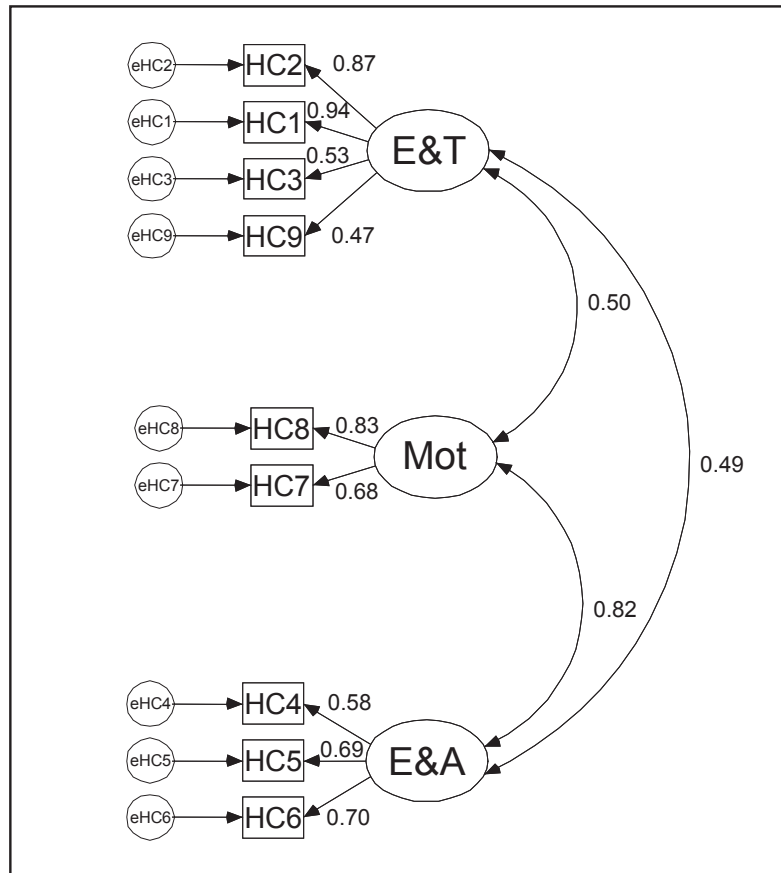


Figure 1. Confirmatory factor analysis for human capital.

Table 4 shows that incremental and global fit measures confirm the accuracy of the analysis.

Table 4  
Analysis for Human Capital

Global fit measures	
Chi-square/Grades of freedom	2.464
GFI	0.952
RMSEA	0.077
Incremental fit measures	
AGFI	0.910
CFI	0.957
IFI	0.958

Regression weights: (Group number 1 - Default model)

		Estimate	S.E.	C.R.	P
HC9	<--- E&T	1.000			
HC3	<--- E&T	1.000	0.162	6.184	***
HC1	<--- E&T	1.918	0.247	7.772	***
HC2	<--- E&T	1.617	0.209	7.746	***
HC7	<--- Mot	1.000			
HC8	<--- Mot	1.401	0.155	9.028	***
HC6	<--- E&A	1.000			
HC5	<--- E&A	0.733	0.085	8.621	***
HC4	<--- E&A	0.576	0.077	7.518	***

### Organizational Capital

Exploratory and confirmatory factor analyses were also performed in order to determine the nature and measure of organizational capital in technology-intensive firms. Table 5 shows that the KMO index is 0.865; hence, the factor analysis is appropriate.

Table 5  
*Exploratory Factor Analysis for Organizational Capital*

Items	CCI	CITs
OC2: Shared values and beliefs towards innovation	0.864	
OC3: Promotion of experimentation and innovation	0.831	
OC5: Managers' support and leader innovation process	0.804	
OC1: Creativity, innovation and development of new ideas are shared cultural values	0.778	
OC4: Employees involved in important decision-making process	0.730	
OC6: Managers have shared beliefs about the future of the firm	0.715	
OC9: Use of CIT in communication, co-ordination and information activities		0.910
OC8: Learning by past experiences using CIT		0.857
OC7: Major part of organizational knowledge is stored in databases, intranet, etc.		0.632
% of Standard Deviation	43.710	26.399
Accumulated %	43.710	70.109

Note. Kaiser-Meyer-Olkin Index (KMO) = 0.865; Barlett's Test (Chi-square, gf) = 1441.438 (36).

The exploratory factor analysis indicated that there were two components of organizational capital which jointly accounted for 70% of the total variance. The first component was labeled culture and CEO commitment towards innovation (CCI). The six items included in this component account for almost 44% of the total organizational capital of a firm. The items concern the firm's values and cultural beliefs and managerial commitment towards the innovation process, with elements such as shared values and beliefs towards innovation, the promotion of experimentation and innovation or managers' support, and the leader innovation process.

The second component accounts for about 26% of the organizational capital and includes three elements. It was labeled communication and information technology in management activities (CITs) and includes aspects relating to technological applications used for managerial and administrative activities, representing the higher factorial weight of the use of CIT in communication, co-ordination, and information activities. Figure 2 shows the factors that make up organizational capital.



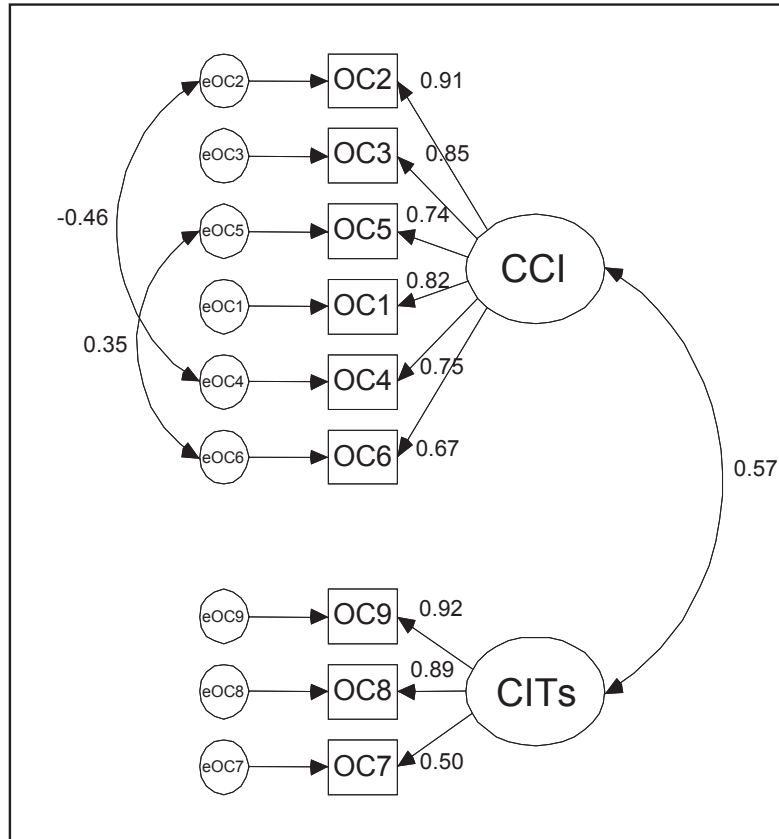


Figure 2. Confirmatory factor analysis for organizational capital.

After the identification of the two factors underlying organizational capital, a confirmatory factor analysis was carried out in order to validate an organizational capital scale. Table 6 shows that incremental and global fit indexes confirm the robustness of the analysis.

Table 6  
Analysis for Organizational Capital

Global fit measures	
Chi-square/Grades of freedom	2.600
GFI	0.950
RMSEA	0.080
Incremental fit measures	
AGFI	0.906
IFI	0.973
CFI	0.973

Regression weights: (Group number 1 - Default model)

		Estimate	S.E.	C.R.	P
OC6	<--- CCI	1.0000			
OC4	<--- CCI	1.3385	0.1270	10.5415	***
OC1	<--- CCI	1.4548	0.1243	11.7009	***
OC5	<--- CCI	1.0777	0.0808	13.3395	***
OC3	<--- CCI	1.3759	0.1133	12.1459	***
OC2	<--- CCI	1.5608	0.1234	12.6514	***
OC7	<--- CITs	1.0000			
OC8	<--- CITs	2.0358	0.2459	8.2806	***
OC9	<--- CITs	2.1191	0.2563	8.2684	***

### Technological Capital

The third part of intellectual capital refers to the knowledge directly linked to the methods, activities, and know-how needed for carrying out efficient productive processes. A similar sequence of steps was followed, and both exploratory and confirmatory factor analyses were performed. Table 8 shows that the KMO index is 0.810; hence, the factor analysis is appropriate.

Table 7  
Exploratory Factor Analysis for Technological Capital

Items	IRD	TKS	ERD
TC1: Percentage of R&D employees above the mean of the industry	0.875		
TC2: R&D cost/sales about the mean of the industry	0.857		
TC3: Formalized R&D department	0.791		
TC6: Endowments of technological knowledge above the mean of the industry		0.901	
TC7: Usefulness of technological knowledge above the mean of the industry		0.885	
TC4: Purchase technology and/or licences above the mean of the industry			0.821
TC5: Cost of contracted technical assistance about the mean of the industry			0.814
TC8: Patent utilization (external)			0.561
% of Standard Deviation	30.080	24.590	24.077
Accumulated %	30.080	54.670	78.747

Note. Kaiser-Meyer-Olkin Index (KMO) = 0.810; Barlett's Test (Chi-square, gf) = 1098.033 (28).

The exploratory factor analysis indicated that there were three components of technological capital, which jointly accounted for almost 79% of the total variance. The first component was labeled internal R&D efforts (IRD). The three items included in this component account for 30% of the total technological capital of a firm and relate to the technological knowledge created and developed within the firm.

The second component accounts for 25% of the technological capital and was labeled technological knowledge stock (TKS). It includes two elements related to the technological knowledge base and includes aspects such as own patents or technological knowledge not legally protected. The last component was labeled external R&D efforts (ERD) and accounts for 24% of the firm's organizational capital; it includes technological knowledge developed outside the firm. Figure 3 shows the factors that make up technological capital.

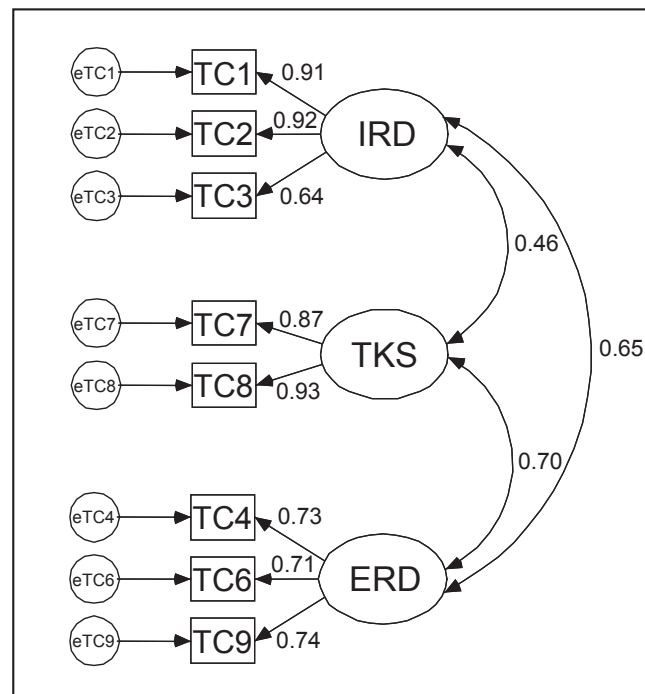


Figure 3. Confirmatory factor analysis for technological capital.

Finally, Table 8 shows that incremental and global fit measures confirm the accuracy of the analysis.

Table 8  
*Analysis for Technological Capital*

Global fit measures	
Chi-square/Grades of freedom	2.269
GFI	0.964
RMSEA	0.071
Incremental fit measures	
AGFI	0.924
IFI	0.980
CFI	0.980

Regression weights: (Group number 1 - Default model)

		Estimate	S.E.	C.R.	P
TC3	<--- IRD	1.0000			
TC2	<--- IRD	1.0920	0.0949	11.5047	***
TC1	<--- IRD	1.0688	0.0932	11.4720	***
TC8	<--- TKS	1.0000			
TC7	<--- TKS	0.9653	0.0683	14.1387	***
TC9	<--- ERD	1.0000			
TC6	<--- ERD	0.7244	0.0729	9.9430	***
TC4	<--- ERD	0.7978	0.0787	10.1359	***

### ***Relational Capital***

The last part of intellectual capital refers to the knowledge generated with other agents and transferred among the firms' agents and their external agents. Exploratory and confirmatory factor analyses were performed in order to determine the nature and measurement of relational capital. Table 9 shows that the KMO index is 0.912; hence, the factor analysis is appropriate.

Table 9  
*Exploratory Factor Analysis for Relational Capital*

Items	C&S	All	Rep
RC4: Development of solutions with suppliers	0.776		
RC2: Development of solutions with customers	0.714		
RC5: Quality and design improvements with suppliers	0.673	0.473	
RC1: Market necessities and trends	0.662		
RC3: Customers' base	0.620		0.420
RC6: Suppliers' base	0.605	0.456	
RC7: Development of solutions with allies		0.833	
RC8: Quality and design improvements with allies		0.829	
RC9: Allies' base		0.789	
RC12: Financial reputation			0.877
RC11: Management reputation			0.819
RC10: Product and service quality reputation			0.806
% of Standard Deviation	26.488	23.669	23.038
Accumulated %	26.488	50.156	73.195

Note. Kaiser-Meyer-Olkin Index (KMO) = 0.912; Bartlett's Test (Chi-square, gf) = 1995.189 (66).

The exploratory factor analysis indicated that there were three components of relational capital which jointly accounted for 73% of the total variance. The first component was labeled customers' and suppliers' relationships (C&S). The six items included in this component account for 26% of the total relational capital of a firm and relate to the vertical relationships maintained for the firm to carry out its main activities, which involve the development of solutions with suppliers and the development of solutions with customers; these elements represent the highest factorial weights.

The second component accounts for almost 24% of the relational capital and includes three elements related to allies' relationships (All). It captures the firm's relations with its allies and includes aspects such as the structure of the allies' base and the improvement of the quality and design of products and processes through those relationships. The element concerning the development of solutions with allies accounts for the highest factorial weight.

The last component refers to reputation (Rep) and accounts for 23% of the firm's relational capital. This component includes the firm's image according to external agents, which will influence day-to-day business activities. Figure 4 shows the factors that make up relational capital.

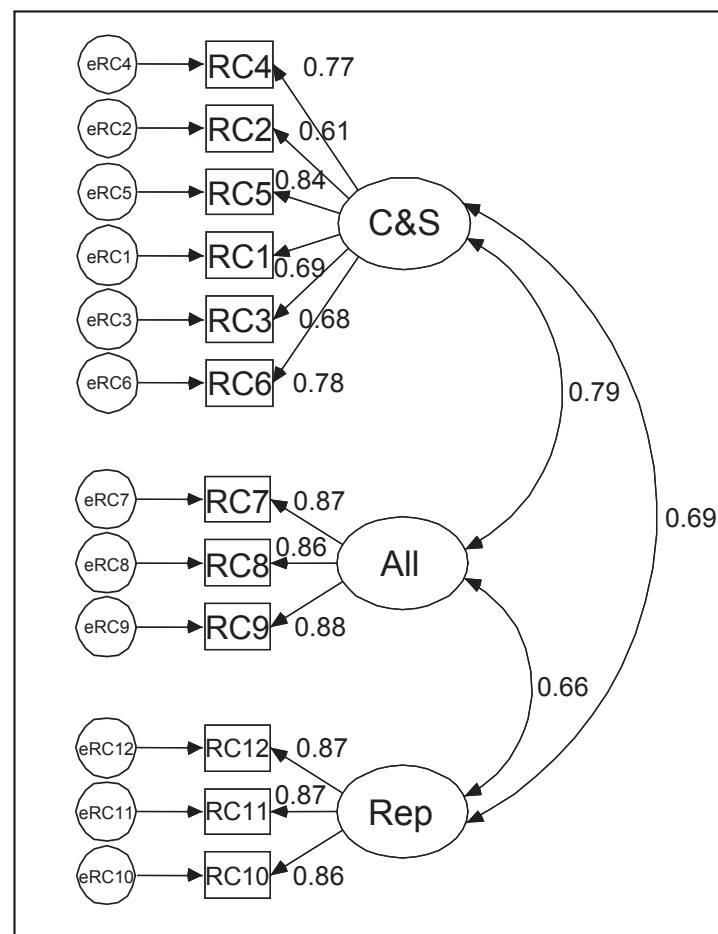


Figure 4. Confirmatory factor analysis for relational capital.

Finally, Table 10 shows that incremental and global fit measures confirm the accuracy of the analysis.

Table 10  
*Analysis for Relational Capital*

Global fit measures					
Grades of freedom/Chi-square	2.655				
GFI	0.914				
RMSEA	0.081				
Incremental fit measures					
AGFI	0.869				
IFI	0.958				
CFI	0.957				
Regression weights: (Group number 1 - Default model)					
		Estimate	S.E.	C.R.	P
RC6	<--- C&S	1.0000			
RC3	<--- C&S	0.8874	0.0808	10.9830	***
RC1	<--- C&S	0.8532	0.0769	11.0946	***
RC5	<--- C&S	0.9910	0.0708	14.0007	***
RC2	<--- C&S	0.9474	0.0972	9.7472	***
RC4	<--- C&S	1.0366	0.0823	12.5913	***
RC9	<--- All	1.0000			
RC8	<--- All	0.9531	0.0540	17.6435	***
RC7	<--- All	1.0149	0.0565	17.9709	***
RC10	<--- Rep	1.0000			
RC11	<--- Rep	1.1280	0.0655	17.2125	***
RC12	<--- Rep	1.1113	0.0638	17.4167	***

## Conclusions

In general terms, managers face increased business complexity. In a competitive situation, standardized solutions and structured processes are not best suited to deal with complexity. For firms to come to grips with the increased rate of change, the increased business complexity, and the increased need for information and knowledge, business activities and operations must respond in a coherent and integrated system. It is in this context that the focus on intellectual capital as a coherent management philosophy comes into play (Johannessen et al., 2005).

The average balance sheet of intellectual capital that could be found in technology-intensive firms might be similar to what is shown in Figure 5. Human capital includes three main components that relate to (a) education and training, (b) motivation, and (c) experience and abilities. Generally speaking, intellectual efforts play a key role in those activities needed for making progress within a firm. Particularly, it seems necessary to invest in resources to promote employees' training because employees who have high training and education levels could be driving forces behind improvements within technology-intensive firms. Employees' motivation and their experience and abilities also play an important role within human capital and represent valuable assets. The technology-intensive firms participating in this study were deeply interested in the education and training of their employees while also trying to reach promising future professionals.

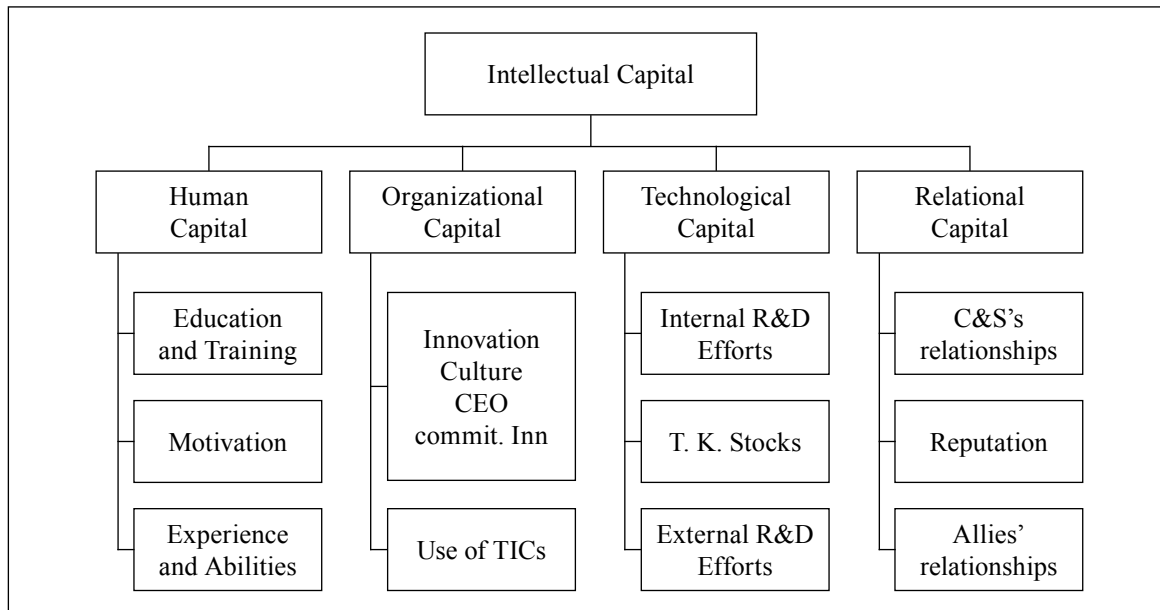


Figure 5. The intellectual capital model.

In the analysis of organizational capital, special attention was paid to issues related to innovative culture, CEO commitment towards innovation, and the use of CITs because these elements are necessary to achieve new knowledge. In this sense, the first two issues are crucial in the context of organizational knowledge and information. It is essential to provide an appropriate context to encourage creativity and the development of new ideas and the CEO's support of innovation in order to continuously adapt to changes in the environment. It is also relevant to consider the use of CITs in managerial activities in order to facilitate communication, cooperation, and coordination within a firm, especially in times of increasing information load. Those aspects can drive knowledge creation and transfer for competitive advantage in technology-intensive firms because they involve support for cultural or innovation initiatives.

Technological capital includes three main components that relate to (a) internal R&D efforts, (b) technological knowledge stocks, and (c) external R&D efforts. Research and development activities play a key role within technological-intensive firms because they represent one of the most important aspects that can help the firms improve existing knowledge and progress towards new knowledge. In particular, the first component is heavily weighted because its elements, such as a suitable staff dedicated to R&D activities, a formalized R&D department, and a high R&D budget measured as expenditure over firm sales, are critical at the beginning of the innovation process. Thus, a firm could obtain better results if it considers its technological knowledge stocks and external R&D efforts jointly in order to take advantage of the diversity of knowledge related to research and development.

Finally, relational capital is divided into three components related to (a) customers' and suppliers' relationships, (b) allies' relationships, and (c) a firm's reputation. The most influential component of relational capital is customers' and suppliers' relationships. For the Spanish technology-intensive firms participating in the study, the most critical nexus with their environment is defined by vertical relationships, showing that the supply chain and sales and distribution could be the leading elements for a successful connection to the industrial markets. Regarding allies' relationships, the IC element may be an important piece in building a consolidated business network. Finally, a good corporate reputation could constitute an effective way to attract and retain relevant business networks: allies, suppliers, customers, and so on.

This study has shown that technology-intensive firms may find intellectual capital to be their cornerstone for competitive advantage. Although several proposals about intellectual capital classification, identification, and measurement can be found in the literature, this study provides evidence-driven classification and configuration of intangible assets for a certain type of firms, which strengthen this specific research stream. As different intangible factors are required depending on the type of industry in which a firm operates, the findings cannot be generalized to all industry types of industry, and implications for managerial practice may be obtained for specific industries only.

Implications for academics and practitioners can be found in the methodology followed to complete this study. Confirmatory factor analyses grant four sets of indicators (for human capital, organizational capital, technological capital, and relational capital) that show the validity and reliability of the results. Future research in the field can be built on these metrics while focusing on other kinds of industries or different geographical settings.

The indicators and the intellectual capital framework can also be useful for managers of information systems in technology-intensive firms because they can be easily adopted as a way of controlling the intellectual capital systems of their firms. Managers must face the following critical challenges in managing their firm's intellectual capital: (a) seizing and developing human capital as the source of success for its intellectual capital and competitive advantage, (b) providing an organizational and technological structure to support the firm's human capital and the structured information and knowledge systems, (c) setting innovation as a corporate mission to retain a successful performance, and (d) designing the map of relationships and alliances needed to enhance their firm's business success.

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