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ESSAYS ON INNOVATION IN MANUFACTURING ENVIRONMENTS : STRATEGY AND PRODUCTION

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ESSAYS ON INNOVATION IN MANUFACTURING ENVIRONMENTS: **STRATEGY AND PRODUCTION**

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CERTIFY

that Josep Llach Pagès carried out the dissertation entitled “ESSAYS ON INNOVATION IN MANUFACTURING ENVIRONMENTS: STRATEGY AND PRODUCTION” under our supervision.

Therefore we sign the present certificate.

Dr. Rodolfo de Castro Vila	**Dr. Pilar Marquès Gou**
Supervisor	Supervisor

Josep Llach i Pagès

PhD candidate

Girona, December 2009

Agraïments

Sempre he considerat que expressar en paraules els sentiments acumulats durant un cert període de temps requereix un gran esforç de concentració i síntesi, però fins i tot encara pot ser més gran quan el període ha estat tant enriquidor com el recorregut des del primer dia que vaig iniciar aquest treball. Per tant, intentaré ser el més acurat possible i no deixar-me ningú. Altrament, demano disculpes per endavant.

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I would like to highlight that all the essays included in the present dissertation contain results that have been presented in international conferences or accepted and some already published in international peer-reviewed journals, as follows:

Essay #1: **'Exploring barriers to R&D cooperation in the Spanish manufacturing sector'** has been presented to the 5th International Conference of the Iberoamerican Academy of Management (IAM) and submitted to the *Journal of Small Business Management*.

Essay #2: Llach, J.; Marquès, P.; Valls, J. (2006) **'Strategic attitudes in the global textiles market: the case of a South European cluster'.** *Fibres and Textiles in Eastern Europe,* Vol. 14, No. 1 (55), pp. 8 – 13.

Essay #3: Llach, J.; Bikfalvi, P.; Marquès, P. (2009) **'What are the Success Factors for Spanish Textile Firms? An Exploratory Multiple-Case Study'.** *Fibres and Textiles in Eastern Europe,* Vol. 17, No. 2 (73), pp. 7 – 11.

Essay #4: Llach, J.; Bikfalvi, A.; De Castro, R. (2009) **'The use and impact of technologies in factory environments. Evidences from a manufacturing survey in Spain'**. *International Journal of Advanced Manufacturing Technologies*, accepted at June 22nd 2009. Available online since 11th July 2009.

Essay #5: **'Relationship between Quality Management Systems and Organisational Innovations'** submitted to the journal *Human Factors and Ergonomics in Manufacturing*.

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Chapter 1. Introduction

Innovation is a popular buzzword nowadays, but it has shaped society and daily life in every age. Its scope is such that academics from completely different fields define broad periods of history in terms of the innovations that distinguish them: the wheel in the Neolithic Age, the steam engine in the Industrial Age or the computer in the current Digital Age.

Although the previous examples of innovations refer to technology, innovation encompasses much more than technology. Indeed, the impact of innovation over the centuries can be seen in such diverse areas of human endeavour as religion, social organisation, architecture or the arts.

Because it has always been inherent in our society, innovation is not a new phenomenon. However, the definition of innovation has always been a source of discussion and research. For instance, scholars have always found differences between invention and innovation. While inventions may be carried out anywhere, in universities for example, innovations occur mostly in firms, though they may also occur in other types of organisations. To turn an invention into an innovation, a firm normally needs to combine different types of knowledge, capabilities, skills and resources. For instance, firms may require production knowledge, skills and facilities, market knowledge, a well-functioning distribution system, sufficient financial resources and other resources.

In the last 20 years, many useful typologies have been proposed to classify types of innovations, each providing insights into our understanding of the innovation process.

Schumpeter (1934) during the first half of the last century distinguished five types of innovations: new products, new methods of production, new sources of supply, the exploitation of new markets and new ways to organise businesses. Now, the Oslo Manual (3rd edition, 2005), written by the Organisation for Economic Co-operation and Development (OECD), the foremost international source of guidelines for the collection and use of data on innovation activities in industry, classifies four types of innovation: product, process, organisational and marketing.

Since its first edition the Oslo Manual has extended the coverage of the innovation concept in every new edition. The objective has been to better accommodate innovation in service industries and non-technological innovations. It has moved towards a wider compass and fuller treatment of non-technological product and process innovation. The first edition was only about manufacturing and the second, while still only dealing with technology-based innovation, did so across a broader range of sectors.

The current edition of the Oslo Manual (2005) defines each type of innovation as follows:

> Product innovation: "*introduction of a good or service that is new or significantly improved with respect to its characteristics or intended uses. This includes significant improvements in technical specifications, components and materials, incorporated software, user friendliness or other functional characteristics*".
>
> Process innovation: *"implementation of a new or significantly improved production or delivery method. This includes significant changes in techniques, equipment and/or software".*
>
> Organisational innovation: *"the implementation of a new organisational method in the firm's business practices, workplace organisation or external relations".*
>
> Marketing innovation: *"the implementation of a new marketing method involving significant changes in product design or packaging, product placement, product promotion or pricing".*

The four types of innovation lead to a generic definition for innovation: "An innovation is the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organisational method in business practices, workplace organisation or external relations".

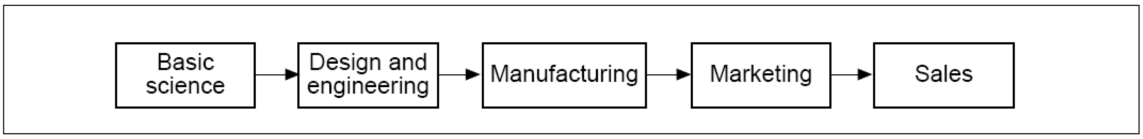
Researchers also differentiate between radical and incremental innovations. This classification is usually based on the degree of change an innovation causes to the structure and processes of an organisation (Damanpour, 1996). Incremental is generally understood to exploit existing forms or technologies. It either improves on something that already exists or reconfigures an existing form or technology to serve some other purpose. In contrast, a radical innovation is something new to the world and a departure from existing technology or methods. The terms *breakthrough* and *discontinuous* are often used as synonyms for radical innovation.

Another recent and similar way to define somewhat the importance of an innovation is to separate it into sustaining and disruptive. Christensen (2003) argues that "*some sustaining technologies can be discontinuous or radical in character, while others are of an incremental nature. What all sustaining technologies have in common is that they improve the performance of established products… Most technological advances in a given industry are sustaining in character… Disruptive technologies bring to the market a very different value proposition than had been available previously*".

In order to analyse the process of carrying out an innovation until it is launched and commercialised in the market, several authors have built up different models to understand better the path and the steps followed during the process.

According to Rothwell (1994), in the early fifties, when the concept of innovation was still understood only in its technological sense, the innovation process was built on the idea that it was a linear process of stages that started with an invention and finished with commercialisation, step by step. Rothwell (1994) defined this linear process as the technology push model.

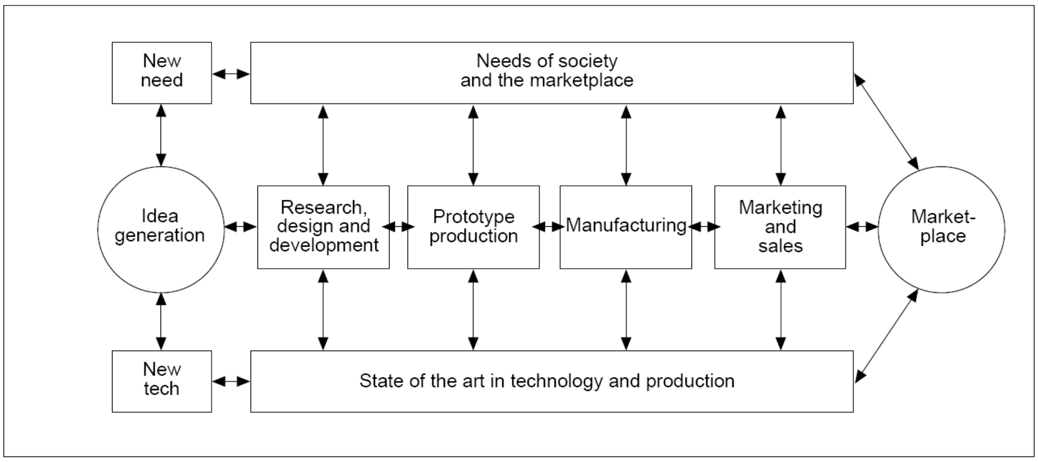
Figure 1.1: Technology push model



Source: Rothwell (1994)

Nowadays, all researchers, managers and policy makers understand the complexity of the innovation process. Authors like Kline (1985) consider that the innovation process is not linear because it consists of a series of feedback and feedforward loops. According to Kline's model, within the innovation process there are five paths that lead to the innovation. Therefore, the major difference between the linear model used during the fifties and Klein's model is that the linear model links science and technology at the initial stages of the process, while complex models connect science and technology at every stage.

Figure 1.2: Complex model



Source: Rothwell (1994)

The impact of the use of technological and non-technological innovations on firm performance has been widely demonstrated in the literature. For instance, Delarue et al. (2008) demonstrate the impact of the use of a non-technological innovation (teamwork) on four dimensions of organisational performance (attitudinal, behavioural, operational and financial) and present a model, based on a sample of studies, that attempts to measure the link to performance directly and comprehensively.

Given the previous statement, that the concept of innovation is not limited to the field of technology, the main objective of the present work is to contribute to two areas of research in the innovation arena. First, to analyse innovation strategy in terms of the technological and strategic positioning or profile of the firm. Second, to analyse production innovation in terms of the use of technological and non-technological innovations in production.

This dissertation is structured in six chapters. The first three chapters are related to innovation management research while the last two chapters are related to research on innovation in production. Finally, a summary of the results, some conclusions and specific implications end the work.

The first chapter proposes a multidimensional technology classification and contributes to the understanding of strategies that low-and-medium-technology (LMT) firms use to acquire new product and process technology, and especially to explore the problems that firms face when engaging in R&D cooperation. The second and third chapters, focusing on the traditional sector of textiles and clothing, explore differences between successful and average SMEs with regard to their technological strategy in the second chapter, and their strategic profiles, including knowledge generation (R&D) and acquisition, innovation activity, product and market characteristics and strategic characteristics in the third. The fourth chapter contains an analysis of the degree of use of advanced manufacturing technologies in the Spanish manufacturing firms and its impact on performance. Finally, in the fifth chapter there is an approach to the use of organisational innovations during the implementation of quality management systems.

1.1. Innovation strategy

A core strategy question is how established firms can sustain their competitive advantage in the face of technological changes and globalisation of markets. Innovation strategy and management, in the last decades, has been among the top priorities on the research agendas of academics, practitioners and policy makers.

The great challenges presented to companies in times of economic turbulence and uncertainly should be turned into opportunities. In international competitions European countries might rely on remaining permanently innovative and developing innovative capabilities. This applies not only to research and knowledge-intensive sectors but also to traditional manufacturing industries.

One of the topics where academics have focused their efforts on understanding innovation strategy and management is the different behaviours of firms according to their technology level. However, the fact that there are not, in the literature, any unique classification criteria has biased researchers to concentrate on the more clearly identified and better-considered high-tech sectors. This bias, and the generated gap of research, due to the failure to agree on criteria, is likely to negatively affect policy and investment decisions (Robertson and Patel, 2007).

The first essay of the next chapter "Exploring barriers to R&D cooperation in the Spanish manufacturing sector" raises again the need to account for the multidimensionality of technological intensity and to consider several patterns of technological intensity. Actually, this paper aims to contribute to the understanding of strategies that low-and-medium-technology (LMT) firms use to acquire new product and process technology, and, especially, to explore problems that firms face to engage in R&D cooperation. Due to the lack of consensus regarding the classification of technology firms, a multidimensional approach to technology-intensity classification proposed by Grinstein and Goldman (2006) is used.

Especially in sectors and companies which are not research-intensive, the industrial ability to innovate is often based on impetus from customer demands, practical knowledge and application experience, or on cooperation with external partners. This perspective of the "systemic character of innovations" essentially points to the question of the interactive relationship among various economic and social agents, each of them with their respective highly differentiated, structural, organisational and cultural conditions in the process of industrial innovation.

In general, in recent years, low-tech sectors have suffered difficult times due the globalisation and liberalisation of some sectors. The textile and clothing (T/C) sector in Europe is not an exception. Spain, the fifth producer in the EU-15 has been involved in an important restructuring of the sector, with the critical effects of downsizing and reallocation (delocalisation) of production. Within such a framework, innovation and cooperation are seen as key issues for competitiveness.

In fact, the second and third essays of this dissertation explore the strategic attitude and success drivers used in Spanish firms to survive in the global market in the T/C sector.

The second essay analyses how Spanish firms face the increased competition of the new liberalised and globalised T/C industry. The analysis of the firms focuses on their technological and adaptive profiles. In particular, the strategic types proposed by Miles and Snow (1978) to analyse the different strategic and technological profiles of the firms is used, discussing the different ways in which the various types of firms face their competitive environments and how this influences their ability to survive in an environment of global competition.

The third essay aims to identify differential traits of successful SMEs in comparison to average SME firms in the T/C sector, based on four main dimensions collected from recent literature: i) knowledge generation (R&D) and acquisition; ii) innovation activity; iii) product and market characteristics; and iv) strategic characteristics.

1.2. Innovation in Production

In the last decades, the implementation of new manufacturing philosophies has turned production processes into more flexible systems. Manufacturing philosophies, like lean manufacturing or total quality management, have appeared on the scenario as crucial for the competitiveness and consequent survival of the firm.

Regardless of the manufacturing philosophy, the main idea that is common in most of the philosophies is that the firm must be willing to satisfy specific and individual customer needs all the time. This has become a way of life, not to say a necessity, for survival in a manufacturing environment that has become increasingly difficult (Zhang and Sharifi, 2000).

This is the reason why the concept of flexibility is often lauded in management journals as a key to success in manufacturing industries. Flexibility is a multidimensional concept that supports organisational responses to environmental uncertainly. For instance, Koste et al. (2004) based on a previous literature review detect six flexibility dimensions: machine, labor, material handling, mix, new product and modification.

The effective deployment of advanced manufacturing technologies (AMTs) has been widely recognised as a means of building a sustainable competitive advantage and thereby enhancing organisational performance. AMTs are defined as technologies concerned with the application of mechanical, electronic, and computer-based systems to operate and control production. AMT adoptions appear to be a key condition for long-term competitiveness. However, many AMT projects fail to meet the expectations of their adopters. Lewis and Boyer (2002) point out that the reasons for failure vary from inadequate attention to implementation factors such as a plant's strategic priorities to misunderstanding of the benefits of AMTs.

In the third chapter of this dissertation, the results of an in-depth analysis of the use of AMTs in 151 Spanish manufacturing firms are presented. Its aim is to report information related to the process of implementation, namely, the proportion of Spanish manufacturing firms that implemented such techniques at a particular time, together with information about the level of usage of those elements. In addition, the impact on a firm's performance according the level of implementation is analysed.

Downs and Mohr (1976) argue that the innovation process is one of the most complex organisational phenomena. In fact, the innovation process requires both technological as organisational innovation efforts.

During the last decades, companies, policy makers and researchers have been searching more thoroughly for accompanying measures to flank their innovation management: innovation activities in additional fields to maintain or regain their lead in innovation. These complementary organisational innovations, already cited by Schumpeter (1934) as non-technical innovations and included in the last edition of the Oslo Manual (2005), are defined as the implementation of teamwork in production, performance-based wage systems or just-in-time concepts (Damanpour, 1987; Damanpour and Evan, 1984).

The importance of organisational innovation for competitiveness has been proved by several studies analysing the impact of organisational innovations on business performance (Caroli and van Reenen, 2001; Damanpour et al., 1989; Greenan, 2003; Piva and Vivarelli, 2002). These studies point to two different results. First, organisational innovations act as prerequisites and facilitators of an efficient use of technical product and process innovations as their success depends on the degree to which the organisational structures and processes respond to the use of these new technologies. Second, organisational innovations present an immediate source of competitive advantage since they themselves have an important impact on business performance in regard to productivity, lead times, quality and flexibility (e.g. Womack et al., 1990; Hammer and Champy, 1993; Goldman et al., 1995).

In order to figure out the use of organisational innovations during the implementation of a manufacturing philosophy like Total Quality Management, the last chapter of this dissertation analyses types of organisational innovations, based on the classification of Armbruster et al. (2008) and correlated with the process of implementation of quality management systems. Quality management systems are not only implemented in firms to obtain an accrediting document that gives certain commercial advantages. The implementation process can be effectively used by managers for the internal organisation of the firm.

Chapter 2. Exploring barriers to R&D cooperation in the Spanish manufacturing sector

Resum

Aquest treball té dos objectius principals, per una part, entendre millor com les empreses d'intensitat tecnològica mitja i/o baixa acostumen a adquirir noves tecnologies de producte i procés, i per altre part, analitzar quines són les principals barreres que aquestes empreses han d'afrontar durant el procés de cooperació en R&D. Les dades utilitzades en aquest treball provenen de 59 entrevistes realitzades l'any 2002 amb directius d'empreses considerades d'alt rendiment, en termes de facturació, sobre els principals aspectes relacionats amb el procés innovador dins l'empresa.

Respecte el primer objectiu, els resultats mostren com una classificació realitzada a partir de diferents indicadors d'R&D, tecnològics i organitzatius ajuda a entendre millor la naturalesa de l'empresa. Aquesta classificació basada en la classificació tecnològica proposada per Grinstein i Goldman (2006) mostra semblances amb els patrons tecnològics de la taxonomia de Pavitt (1984).

Per altre part, els resultats referents a les principals barreres detectades durant el procés de cooperació en R&D, mostren com les principals causes de la mancança de cooperació entre empreses és inherent a la pròpia empresa en el cas de la cooperació entre empreses, mentre que entre empreses i centres de recerca/universitats la principal barrera és una mancança de resposta d'aquests agents davant les necessitats del mercat.

Els resultats obtinguts tenen implicació en tots aquells agents no només relacionats en la creació de polítiques que promoguin la cooperació del R&D sinó en tots aquells que juguin un paper de facilitadors.

Abstract

This paper aims to contribute to the understanding of strategies that low-and-medium-technology (LMT) firms use to acquire new product and process technology, and especially to explore the problems that firms face to engage in R&D cooperation. Our data comes from in-depth interviews carried out in 2002 with executives from 59 high-performing SMEs in the Spanish manufacturing sector. Regarding the technology-intensity classification used to analyze the firms, our data reveals how a multidimensional analysis of technological intensity provides a better classification of firms, dividing firms into four distinct groups and visualizing their technological patterns, that share important similarities with Pavitt's (1984) taxonomy.

The analysis also reveals the necessary conditions to engage in R&D cooperation. The main barriers perceived to engage in cooperation are internal to the firms: lack of sufficient internal R&D and difficult knowledge absorption. When collaboration takes place with universities or other public research institutions, respondents name unresponsiveness to industry needs as a high barrier to cooperation.

The results have implications for the actors involved in the promotion of innovation and of R&D cooperation, including policy makers as the likely facilitators of these processes.

2.1 Introduction

Low-and-medium technology (LMT) firms account for most of GDP, number of firms and employment in developed and developing countries. Yet high technology (HT) firms, which are attributed with the leadership in technological change and innovation, only make up a small percentage of these key figures.[1] Indeed research proves that industries with greater levels of research and development intensity are home to higher rates of firm-level innovative activity (e.g. Thornhill, 2006). However, the causes and effects of innovation produced in HT sectors are strongly linked to the existence of the LMT sector, due to three main reasons (Robertson and Patel, 2007): i) the impact of innovation diffuses across all sectors; ii) the best customers of HT producers are LMT firms, determining the size of the market for innovations; and iii) R&D activities are rarely confined to HT sectors. For these reasons, the existence and benefits of the innovations generated in HT sectors depend on the health of the LMT sectors.

Given the above rationale, LMT sectors may have different roles in the global innovation process: adopting innovation, demanding innovation as important future purchasers, or complementing HT innovations with more R&D (to learn, absorb, enhance, or imitate innovation).

The first step to study LMT firms is the delimitation of LMT versus HT firms. This is not a simple endeavour. There is a lack of agreement in the literature about the specific criteria to be used in classifying firms according to their technology level (Grinstein and Goldman, 2006; Koberg et al., 1996). This failure to agree on criteria is likely to negatively affect policy and investment decisions (e.g. Robertson and Patel, 2007), and it biases researchers to concentrate on the more clearly identified and better-

[1]For example, it is estimated that high-tech sectors account for less than 10% of GDP in US, and thus LMT would represent 90% or more (Robertson et al., 2003).

considered high-tech sectors. This relegates low and medium technology sectors to a secondary research field. Addressing this problem, Grinstein and Goldman (2006) revise the main characteristics associated to technological intensity and summarise them into 19 characteristics. We will use their proposal later in the paper to structure and analyse part of our empirical data.

The importance of R&D cooperation is already acknowledged (e.g. Veugelers and Cassiman, 2005; Debackere and Veugelers, 2005; Montoro-Sanchez et al., 2006), and is generally recommended to firms of all dimensions and of all technological intensities. In the case of LMT firms, it is reasonable to contend they are likely to benefit from R&D cooperation, since they have a limited internal R&D capability. Cooperation may also be important to upgrade their technological capabilities. However, the rates of cooperation for LMT firms are not high, especially in some countries, including Spain (e.g. Bayona et al., 2002), where we carry out our research. It is therefore worth analysing what prevents or hinders cooperation, since the benefits of cooperation are acknowledged for all parties, whether firms or research organizations (e.g. Hall et al., 2003; Montoro-Sanchez et al., 2006; Mora-Valentin et al., 2004).

The Catalan agency for innovation and development (CIDEM) acknowledged this importance and contracted research on the relationship of R&D cooperation and high-performaning SMEs, where performance is viewed in terms of sales growth and sustained profitability (Sole et al., 2003). However their analysis found that R&D cooperation was not a common trait of the 59 firms surveyed, using basically descriptive and univariate analysis. Only 23 firms out of 59 revealed some external R&D, and only 18 firms had R&D contracts in the three years previous to the survey. The main common traits among the sample of high performing firms were: the belief that innovation was a key success factor, necessary to grow in current and new markets;

their international focus, higher than average; the relative dominance of product over process innovation; and that, though R&D indicators were low, they were still innovating. Also, all except one firm belonged to sectors traditionally classified as LMT.

To investigate further the technological features and patterns of these firms, this paper will use a multivariate analysis of the data obtained in the survey, following the proposal of Grinstein and Goldman (2006). In this way we aim to contribute to the understanding of the technological characteristics of LMT firms, the strategies that these firms use to acquire new product and process technology, and to explore the problems that firms face when considering or engaging in R&D cooperation.

Our empirical findings using multidimensional scaling reveal that two dimensions are important to account for the richness of data about technological intensity for our sample of LMT firms. These two dimensions comprise several R&D indicators and other proxies of technological and organizational features. We show how this multidimensional analysis of technological intensity provides a better classification of firms, dividing firms into distinct groups and visualizing their technological patterns and the necessary conditions to engage in R&D cooperation. R&D cooperation is found above a certain level of R&D activity, which is the first dimension found. We also shed some light on the key success factors for the firms that have low R&D activity (expenditure, personnel and outsourcing) confirming some recent findings on technological patterns.

We contribute to structuring a more systematic and explicit treatment of barriers to cooperation, building on theory and exploring the empirical results. We deal with barriers to cooperation in general and particularly when the partners are universities and other public research institutions. Therefore, the aim of this paper is also to contribute to a better understanding of the occurrence of R&D cooperation by examining industry demand for it. Our findings on barriers to cooperation and technological patterns have implications for policy makers.

The paper is organised as follows. The next section provides the theoretical background on the classification of firms according to technological intensity, the taxonomies of technological patterns, and the barriers to R&D cooperation. In Section 3 we present the sample and the main methods used to obtain the results, which are then presented and analysed in Section 4. Section 5 concludes the paper outlining contributions, policy implications and limitations.

2.2. Theoretical background

2.2.1. Technological intensity classification for LMT

While there is a consensus that technology firms emphasize technological activities and technology-based innovations, there is a lack of agreement in the literature about the specific criteria to be used in classifying firms according to their technology level (e.g. Grinstein and Goldman, 2006; Koberg et al., 1996). Since there is no clear directive, many researchers use firm's industry membership as the defining criterion, or they choose a single criterion, such as R&D expenditure. Some use a number of characteristics that are usually associated with technological intensity. However, all these choices have both advantages and disadvantages. Many researchers have tried to uncover the differences between high technology firms and others (e.g. Baruch, IJTM 1997; Felsenstein and Bar-El, 1989; Koberg et al. 1994), but no consensus has been reached.

2.2.2. Technological patterns for LMT firms

The lack of consensus on the classification of firms hinders the task of describing the expected technological characteristics of these firms. Literature provides multiple classifications. In a recent article, Grinstein and Goldman (2006) address this issue. They scan literature to characterize the technology firm and derive 19 defining characteristics. For each they provide guidance to define three levels of technological intensity: low, medium and high. Thus, they propose a multidimensional characterisation of technological intensity achieved using multivariate analysis to find the underlying distinctive dimensions. According to their extensive characterisation, typical LMT firms would have the following description:

– Low and medium levels of R&D indicators (investment, personnel, and outsourcing) respectively;

– They emphasize more development than applied research;

– Their management commitment to R&D is inexistent or limited, respectively;

– Their innovation does not drive R&D or only moderately does so;

– They launch a reduced number of products of which less than 10% are really new;

– Their product's life cycle is long, and customers are not technology driven;

– Their product development follows customers' requests or follows market needs, but does not create market needs;

– Their competition is not product-driven, it is at least partially driven by other aspects, such as price or promotion;

– Their management is reluctant to change and more risk-averse;

– They also make less use of the main organizational systems that promote innovation such as flat organizational structures, cross-functional teams, R&D personnel movement, lateral career paths, incentive systems, and decentralized decision- making.

We will use these items and the method proposed by Grinstein and Goldman (2006) to explore the technological characteristics of the firms in our sample (detailed in Section 2.3).

A more classical and acknowledged contribution to explain technological profiles comes from Pavitt (1984), that proposes four types of sectoral technological patterns for innovating firms in manufacturing and service sectors. These patterns are explained in terms of their sources of technology, requirements of users, and possibilities for appropriation. We will use this taxonomy to analyse the results obtained by characterising the technological intensity of firms following Grinstein and Goldman (2006). The main features of each of Pavitt's technological patterns are presented below.

Supplier dominated firms

These are generally small in size, and weak in internal R&D and engineering capabilities, and thus appropriate more on the basis of professional skills, aesthetic design, trademarks and advertising. They acquire technology by purchasing from suppliers, and are only capable of making minor innovations to such technology and knowledge, mainly related to process innovation. They may also learn from customers or public-financed research institutions or programmes. They have a cost cutting focus, mainly related to labour cost reduction since they do not make significant innovations in product or in process, and this makes them price-acceptant for outputs and inputs. Supplier dominated firms can be found mainly in traditional sectors of manufacturing, such as textiles, lumber, or wood and paper.

Scale-intensive firms

Scale intensive firms are typically big firms that appropriate from economies of scale and productivity gains, associated to firm's size and process innovations, in turn.

They produce for two types of price-sensitive users: producers of standard products and those producing consumer goods and vehicles. Technological skills are used to exploit these economies and cost-cutting, requiring the capacity to design, build and operate large-scale continuous processes and integrated assembly-lines. Engineering teams work mainly to enhance productivity, and only seldom innovate in equipment to improve productivity further. Technological lead is maintained through know-how, secrecy on process innovations, time-lags needed by imitators, and patent protection. They have mostly internal R&D for process innovations, but further they may acquire technology and know-how from suppliers, with whom they have a close complementary relationship. These type of firms are found mainly in food products, metal manufacturing, shipbuilding, motor vehicles, and glass and cement production.

Specialised suppliers

These are small-scale suppliers of equipment and instruments. They have a high proportion of internal R&D and produce product innovations for their customers, mainly scale-intensive firms. There is a symbiotic relationship with their customers: they learn from the operating experience of their customers, and in exchange they pay back specialized knowledge and experience as a result of designing and building equipment for a variety of users in many industries. Their technological trajectory is oriented towards performance-increasing product innovation. Competitive success depends considerably on firm-specific skills reflected in continuous improvements in product design and performance, and the ability to respond sensitively and rapidly to user’s needs. They are typically found in the machinery and instrument sectors.

Science-based firms

Their main sources of technology come from internal R&D activities, based on the rapid - and sometime previous - development of the underlying science in universities and elsewhere. The rich applications based on science discovery leads these firms to grow rapidly and concentrate technologically in their sectors. The sophistication of knowledge, dynamic learning economies, and the fast path of innovations, act as entry barriers for firms outside these sectors. The relative balance of product and process innovations varies across firms. Firms appropriate their innovation leads through a variety of methods including patents, secrecy, natural technical lags, and firm-specific skills. Some firms have managed to enter with aggressive product innovation and the exploitation of steep dynamics economies of scale. In sum, science-based firms are big innovators, providing important innovations to other firms, and are to be found in the chemical, electronic and electrical sectors.

Pavitt's taxonomy does not classify firms into high, medium and low technological sectors. However, the inspection of sectors and the comparison with a standard sectoral classification, such as that of the OECD, allows the association of scale-intensive and supplier-dominated types to low and medium technological sectors – these two groups are described as having lower levels of R&D and innovation (e.g. Souitaris, 2002). It is mostly expected that the main source of technology for LMT firms is the acquisition of embodied technology from high-tech sectors (Robertson and Patel, 2007).

Pavitt's (1984) article and its extension in Tidd et al. (2001) are grounded in data on very large firms. More recently, de Jong and Marsili (2006) have also used this taxonomy for small and micro firms (below 100 employees) in both manufacturing and services. Their findings indicate that these firms differ not only in their innovative activities, but also in their business practices and strategies – such as management attitude, planning and external orientation, used to achieve innovation. They find an additional type of firm, termed resource-intensive, that is similar to the supplier-dominated type but that appears to allocate financial and time resources to innovation.

Souitaris (2002) validates Pavitt's taxonomy on a sample of Greek firms, finding that the different patterns are associated to different rates of technological innovation: specialised suppliers and science-based firms present higher rates of innovation than the other two types. He also argues that Pavitt's taxonomy can contribute to explain the determinants of technological innovation and finds that different variables are associated with innovation for each category of firm. For supplier dominated firms, innovation is related to the competitive environment, acquisition of information, technology strategy, risk attitude and internal co-ordination. For scale-intensive firms, innovation is associated to fund raising, and the education and experience of personnel. For specialised suppliers, innovation is associated with high growth rate and exporting, as well as training and incentives offered to the employees to contribute to innovation. Science-based firms depended upon technology-related variables, education and experience of personnel, growth in profitability and learning from customers.

Innovative behaviour can be a strategic option, when a firm can choose its innovation strategy. However, in some industries, innovation behaviour can be a requirement more than an option. This is the implicit assumption of sectoral works seeking to find the common behaviour within a sector. For example, see Pavitt (1984), Tidd et al. (2001), and the recent work of Jong and Marsilli (2006). It is also the assumption of classifications based on industry belonging. However, recent evidence finds that patterns are more complex, since the so-called LMT sectors are getting increasingly involved in knowledge creating activities in high-tech fields (e.g. Robertson and Patel, 2007; Mendoca and von Tunzelmann, 2004; von Tunzelmann and Acha, 2004) revealing some upgrading of their own technological capabilities.

2.2.3. The importance of R&D cooperation

R&D collaboration, understood here as defining and conducting R&D projects jointly between firms and science institutions, either on a bilateral or on a consortium basis (Debackere and Veugelers, 2005), has the objective to bridge the gap between academic research, technological development and commercial activities (Montoro-Sanchez et al., 2006; Jones-Evans et al., 1999). Both formal and informal collaboration are common place (Bönte and Keilbach, 2005; Krücken, 2003; Meyer-Krahmer and Schmoch, 1998). Still, our attention here is focused on formal cooperative agreements which are easier to follow-up and quantify.

The latest policy trends include the design of different global, national, regional and local support and promotion mechanisms in order to achieve higher levels of interactions in terms of amount, frequency and complexity. Moreover, special emphasis and attention is oriented to firms' interaction with research organizations (ROs) and public research institutions (PRIs). This is due to the differentiated characteristics and modus operandi of each in a context where science oriented actors provide knowledge to firms who transform it into commercializable innovations. The necessity of co-evolution of science and technological knowledge (e.g. Nightingale, 2004) justifies the need to study barriers inhibiting industry to partner with academia.

Due to their multiple facets, different streams of literature analyze cooperative agreements. Examples for such can be transaction cost economics, strategic management, industrial organization, and institutional theory, literature in the management and technology policy domain (Belderbos et al., 2004; Veugelers and Cassiman, 2006; Hagedoorn et al., 2000; Gulati, 1995). These theories are complemented with empirical evidence from large-scale surveys, ad-hoc studies and case studies mainly studying the determinants of cooperation, the link between cooperation and innovation, and the motives and benefits of cooperative agreements.

Firms traditionally have two main options of knowledge generation for innovation: make – using internal capacity- or buy – through outsourcing activities (Veugelers and Cassiman, 1999). Cooperation arises as a hybrid form of this *make-or-buy* function and, from a firms point of view, may be a means of complementing insufficient internal resources related to knowledge, technology or people. They find solutions in their immediate environment from competitors, suppliers, customers, research centres and/or universities in order to share risks and costs, to improve their competitive position, and to access new markets.

However, cooperative agreements resulting from such joint research partnerships are not without problems, which should be clearly differentiated and assessed by partners. If care is not taken, especially with academia-industrial projects, the benefits of such collaborations can be nullified by the many possible barriers and problems.

These arguments complemented with low cooperation levels in Europe in general, and Spain in particular, motivate us to study R&D cooperation, particularly involving universities. Although cooperative agreements may present many research directions, we believe that attention should be focused on barriers to cooperation, as inhibitors of these kinds of agreements.

2.2.4. The determinants of cooperation intensity: barriers

There is a wealth of literature available on barriers to cooperation agreements with industry. We understand by *implicit barriers*, those factors hampering cooperative agreements that we learn in literature but normally indirectly, or from other contexts or circumstances. For example, studies focusing on the determinants of cooperative agreements, factors affecting their success, and motives to initiate collaboration, deal indirectly with barriers. Conversely, *explicit barriers* are those aspects directly considered as barriers and sometimes tested as such. This delimitation is important in order to analyse the received literature and uncover the existing gap.

Empirical studies treating motives and reasons (Montoro-Sanchez et al., 2006; Belderbos et al., 2004; Miotti and Sachwald, 2003; Freel, 2003; Bayona et al., 2001, 2002; Hagedoorn, 2000), benefits and outcomes (Becker and Dietz, 2004; Mora-Valentin et al., 2004; Mowery, 1998), and institutional support (Debackere and Veugelers, 2005; Krücken, 2003; Howells and Nedeva, 2003; Jones-Evans et al., 1999) for R&D cooperation often mention barriers, but do not empirically contrast them. Still, they are important because they provide a starting point for research with a specific focus on barriers. However, there is a clear imbalance between theory and evidence. We agree with Hall et al. (2001) who state there is a lack of research that has attempted to systematically identify barriers that inhibit industry from participating with universities in research projects. However, there is some empirical evidence that it is presented below.

Meyer-Krahmer and Schmock (1998), in a survey of German universities, asked professors within research centres about explicit barriers. The results rank the disadvantages of interaction between universities and industrial firms, from the perspective of academic researchers, including short-term orientation, limited industrial application or relevance, restrictions regarding publishing findings, less interesting topics, administrative problems and unfair terms of contract.

Examining the other perspective, Martinez and Pastor (1995) surveyed 96 Spanish manufacturing firms on the problems experienced in formal university links, uncovering frequent delays in the fulfilment of objectives, university staff being too theoretical, too many regulations, financial difficulties, cultural barriers, disharmony and discord during R&D development, and intellectual property disputes.

Asking both sides, Rogers et al. (1998) study the main obstacles to the development of CRADAs (cooperative research and development agreements) perceived by 59 private company partners and the US federal R&D laboratory. The main obstacles are the same for both sides, but ranked differently. They include complicated administrative procedures, intellectual property rights, the length time to establish a CRADA, insufficient funding, US government/restrictions on the private partner, industrial liability, anti-trust laws, and fairness of opportunity.

Still in the US, Hall et al. (2001) investigates whether there are identifiable barriers – related to intellectual property rights in particular- that inhibit firms from partnering in research with universities. They present evidence from 38 ATP (Advanced Technology Program) projects. The variety of direct-response and open-ended questions transcribed as representative remarks from lead participants is a valuable contribution

Fontana et al. (2006) in the framework of the KNOW survey conduct 70 interviews in which respondents identify reasons for not collaborating with universities. Responding firms cited discrepancies between the objectives of the two parties, the length of time involved in university research, the different focus and different research questions addressed by universities and firms, cultural differences, uneasiness with "open science" disclosure procedures, and the fact that universities lag behind industry in some sectors.

Table 2.1: Barriers to cooperation in general

Intra firm barriers	**Definitions**	**Authors**
Difficult knowledge absorption	Differences in aims, objectives and management styles Differences in objectives and research topics addressed Science versus technology orientation Those in the "Ivory Tower" versus those looking for short-term solutions Communication and complexity Tacit nature of knowledge	Montoro et al. (2006) Fontana et al. (2006) Montoro-Sánchez et al. (2006) Rogers et al. (1998) Bayona et al. (2002)
Difficult knowledge exploitation	Nature of knowledge Knowledge complexity	Debackere and Veugelers (2005) Montoro-Sanchez et al. (2006)
Insufficient size	Firm size Number of employees	Fontana (2006) Sakakibara (2001)
Lack of internal R&D	Intrafirm R&D investment R&D capacity Substantial in-house capacity Firm's R&D activity and status	Fontana (2006) Freel (2003) Sakakibara (2001) Mowery (1998)
Underused internal R&D	Enhance R&D productivity through cooperation on R&D inputs	Sakakibara (2001)
Lack of technological surveillance	Monitoring technology and market Gatekeeping	Belderbos et al. (2004) Fritsch and Lukas (2001)
Inter partners barriers	**Definitions**	**Authors**
System and modus operandi differences	Cultural differences Lack of understanding of partner's culture and objectives Different ethical code and work organization Different organizational routines and styles	Montoro-Sanchez et al. (2006) Veugelers and Cassiman (2005) Jones-Evans et al. (1999)
Complex and expensive management	Expensive, risky and complex research projects	Miotti and Sachwald (2003) Mowery (1998) Rogers et al. (1998)
Unsatisfactory previous experiences	Previous cooperative experiences	Mora-Valentin et al. (2004)
Excessive legislation, regulations and bureaucracy	Institutional organization Bureaucratic layers Administrative problems Statutory and administrative requirements Too many regulations	Mowery (1998) Martinez and Pastor (1995) Debackere and Veugelers (2005) Krücken (2003) Howells and Nedeva (2003)

Table 2.2: Barriers to cooperation with universities

Intra university barriers	**Definitions**	**Authors**
Inapplicability of projects	Basic research Non-codifiable nature of scientific know-how	Debackere and Veugelers (2005)
Unresponsiveness to industry needs	Science-oriented nature of researchers Publication versus commercialization; University staff distracted from academic functions Poor incentives to work with industry	Tether (2002) Howells and Nedeva (2003) Rogers et al. (1998) Meyer-Krahmer and Schmoch (1998) Martinez and Pastor (1995)
Academics' task/work inefficiency	Long research timing Slow to act Lack of trust in the ability of academics to perform tasks efficiently Delays in the fulfilment of objectives Difficulties to perform tasks to a predetermined schedule University staff are too theoretical and not very practical	Montoro and Mora (2006) Jones-Evans et al. (1999) Rogers et al. (1998) Martinez and Pastor (1995)
Lack of technical and scientific resources	Lack of competences for research commercialization Lack of financial resources	Chiesa and Piccaluga (2000) Jones-Evans et al. (1999)
Inter partners (university - firm) barriers	**Definitions**	**Authors**
Cultural and modus operandi differences	Lack of understanding of partner's culture and objectives Different ethical code and work organization Different organizational routines and styles	Montoro-Sanchez et al. (2006) Veugelers and Cassiman (2005) Jones-Evans et al. (1999)
Lack of trust for diffusion	Trust Commercialization versus publication Restrictions on the use of results	Mora-Valentin et al. (2004) Hall et al. (2001, 2002) Jones-Evans et al. (1999)
Results sharing and use	Intellectual Property Rights Patents Open science	Fontana et al. (2006) Montoro-Sanchez et al. (2006) Hall et al. (2001, 2002)
Excessive legislation, regulations and bureaucracy	Institutional organization Bureaucratic layers Administrative problems	Debackere and Veugelers (2005) Krücken (2003) Howells and Nedeva (2003)
Unsatisfactory previous experiences	Negative previous cooperative experiences	Mora-Valentin et al. (2004)
Geographical distance	Proximity between partners Physical distance	Bayona et al. (2002)

Based on both implicit and explicit barriers found in the presented literature we separate between general barriers and university specific barriers. We further distinguish within each main type: 1) *intra or partner-specific barriers* and 2) *inter o partnership specific barriers*. The first category refers to those problems that either firms or universities might face due to their own characteristics, that may be perceived by firms (industry) as barrriers to cooperation. The second category embraces those problems that complicate the relationship between the participating institutions, as may be perceived by firms. Table 2.1 and Table 2.2 present the classification of barriers that we propose, and how it is grounded on literature.

Once barriers are identified remedial action is necessary to facilitate cooperation and improve the success of research partnerships. In this regard, one of the main characteristics of the few empirical studies which focus on barriers is that companies having no collaborative agreements are not surveyed. It would be interesting to differentiate between those barriers preventing firms to enter cooperative agreements in the first place, and those encountered during collaboration.

2.3. Empirical research

The empirical analysis presented in this paper is based on 59 in-depth interviews carried out between February and October 2002 with executive managers, normally general managers who in some cases were also the owners or founders (entrepreneurs) of the SME firms.

2.3.1. Sample: selection criteria

Our sample consists of high performing SMEs from the manufacturing industry, in the Catalan region of Spain. High performance was mainly understood as sales growth and sustained profitability. The research approach required lengthy and open-ended interviews, and thus the size of the sample was limited. The original study (Solé et al., 2003) intended to interview a maximum number of 70 high performing firms, in the manufacturing sector, assuming that they would mostly be LMT firms since the regional manufacturing sectors are very diversified. The random sample of this size finally contained firms with an annual rate of sales higher than 6% in the 3 years previous to the study, an annual economic profitability higher than 5% in the same timeframe, and a minimum annual turnover of 2,5M€ the previous year. With this context and criteria 59 interviews were completed.

The firms responding to the survey belong to a wide range of manufacturing sectors, including metal products, plastic and rubber, textile, chemical firms (except pharmacy) and mechanical machinery. These represent over seventy per cent of the sample. Other firms belonged to the food and beverages sector, wood and paper, electrical machinery, other metal products, non-metallic minerals, and other manufacturing. Included was a firm in the optical instruments sector, the only one that would be considered HT according to the OECD's sectoral classification. We did not remove this firm from the sample because we clearly perceived that its technological intensity was not higher than many other firms in supposed LMT sectors.

2.3.2. Measurement and interviewing

In order to increase the response rate, and to capture the detailed nature of technological intensity and patterns, teams of 2 or 3 researchers conducted personal interviews with executives in each of the firms. Prior to the interview a short description of the study was sent out, followed by a telephone call based on written guidelines for establishing the interview's exact date and terms. The personal interviews gave the researchers confidence that the concepts of the questionnaire were well understood by the executives. The interviews lasted an average of two hours, depending on the openness of respondents to disclose information.

The interview consisted of two parts. The first involved in-depth open-ended questions. In the second part, the executives were asked to evaluate quantitatively several aspects that may already have been analysed qualitatively. Both parts delivered three main data. Firstly, R&D activity and technological characteristics, comprising R&D expenditure, personnel, outsourcing, type of research, R&D contracting, patenting, technology or knowledge transfer, technological positioning, sources of ideas for innovation, sources of technology and knowledge acquisition, balance between product and process innovations, and barriers to cooperation. Secondly, product and market characteristics, such as the number of new products, the length of life-cycle, type of users, drivers of competition, importance of product design, and export orientation. A third area contained strategic and organizational characteristics, such as key success factors, impact of innovation, commitment to R&D, perception of R&D cooperation, attitude towards risk and change, use of cross-functional teams, and incentive systems.

In the final part of the conversation, general managers had to fill in a prepared checklist containing relevant quantitative factors. This step was important in order to ensure the capture of the respondent's exact perception on important matters. After every interview, the team discussed the data collected. A database, for all, and a case report, for each, were the two instruments for codifying and saving the notes from the visits.

Although previous questions gave hints as to whether executives considered R&D outsourcing necessary in order to maintain and improve their competitiveness, as well as the number of contracts formalized with universities, we decided to ask all participants about barriers to cooperation. Originally, it was considered important to question all managers –not only those who collaborated in R&D- because there could also be absolute barriers preventing firms from collaboration – and their effects would result in no collaboration taking place. Conversely, relative barriers do not necessarily prevent firms from cooperation but make it more difficult. To evaluate barriers, managers responded to 10 items for barriers to R&D outsourcing and 10 more for barriers to cooperating with universities or other PRIs, using a 10-point Likert scale (0 meaning not a barrier, 5 for a surmountable barrier, 10 for an insurmountable barrier).

Most of the previous research on defining and classifying technological intensity relies on judgements of researchers or experts (e.g. Medcof, 1999; Shanlin and Ryans, 1987). We are only aware of two works that use managers' responses. They are Grinstein and Goldman (2006), and Baruch (1997) that studied only "high-technology" organizations. Executives are a relevant source of information, since they know the activity of their firms in detail, including their strategic operations, technology, innovation, and organizational systems. They can also provide answers to their attitudes towards innovation and change.

The main limitation of relying on executive responses is the so called self-reporting bias. To control this, we used "neutral" questions relating firm position on several characteristics and unrelated to firm performance. The open-ended questions needed to be analysed and categorised by interviewers afterwards. This allowed the research team to check for bias immediately afterwards. However, we found that the degree of agreement of both judgements was general.

2.3.3. Methods of analysis

Our survey data covers all of Grinstein and Goldman's (2006) 19 characteristics except 4, that were unavailable to us or very difficult to codify objectively into the three technological levels (low, medium, high) according to their definition. These were innovative R&D and three characteristics of their organizational systems (decentralised decision-making, lateral career paths, and flat organizational structure). Due to the statistical method used, multidimensional scaling (MDS), characteristics with many missing responses also had to be removed from MDS, although the information is analysed descriptively later, in Table 2.3. These characteristics were: technology-driven customers, product-driven competition, management attitude towards risk, and R&D personnel movement. This caused the MDS to be completed with 11 characteristics. Appendix 2.A provides the correlations among the 11 variables.

In the data analysis we used two methods, multidimensional scaling (MDS) to identify the dimensions underlying the set of eleven characteristics associated with the technology firm, and categorical principal component analysis (PCA) to support the analysis carried out in the previous step. We decided not to use the PCA as the main method because PCA may suffer from having too few observations (Evangelista, 2000; Peneder, 2002). Due to space limitations we do not reproduce the results of PCA here.

MDS is a multivariate technique that represents in a geometric space of few dimensions the distance between a set of objects and variables. MDS was shown to be appropriate for small samples and for exploratory research (Mullery et al., 1995) and has proved particularly helpful in previous research where the focus was on identifying the dimensions underlying the phenomenon investigated (Padula et al., 1998).

In our case, the size of the sample is bigger than other studies where MDS has been employed, as described by Grinstein and Goldman (2006). The main limitation of MDS is the fact that it allows for subjective interpretation of the output (Gartner, 1989). However, this limitation is also present in many other compositional techniques such as factor and cluster analysis. For this reason we use MDS and the results of PCA to produce a less subjective interpretation of results.

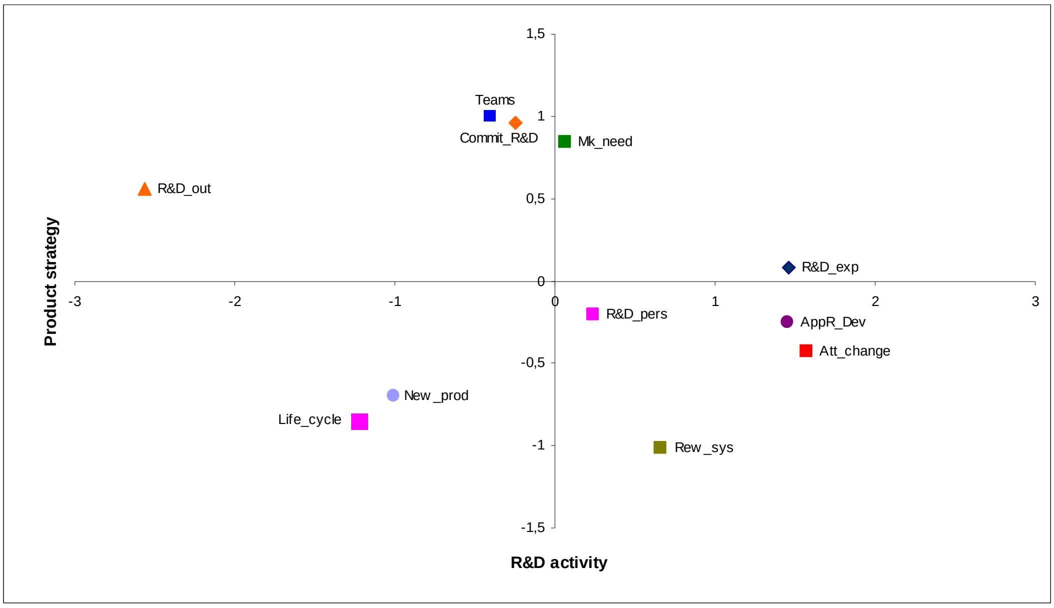
2.4. Empirical findings for LMT firms

2.4.1. The dimensions of technological patterns

To uncover the dimensions underlying technological intensity we carried out MDS on the 11 available variables. We used an Euclidean distance model and examined solutions from 1 to 5 dimensions for interpretability and goodness of fit, examining the two widely used criteria: STRESS, measuring the degree to which the derived estimates deviate from the original data and the derived distances, and RSQ, the square correlation between the original data and the derived distances. We selected the two-dimensional solution, with a STRESS of 0,184 and RSQ at 0.829. The goodness of fit is acceptable as a better fit is produced when STRESS is close to 0 and RSQ close to 1 (Padula et al., 1998). The distance coordinates for this solution are provided in Appendix 2.B.

MDS produces a perceptual map of variables (presented in Fig.1 below) where variables are distributed following the two main dimensions found in the data. To interpret these dimensions we examined the position of the variables, and we used the assistance of the results produced in the categorical PCA, which is also appropriate for our research.

Figure 2.1: MDS output for 11 variables of technological intensity

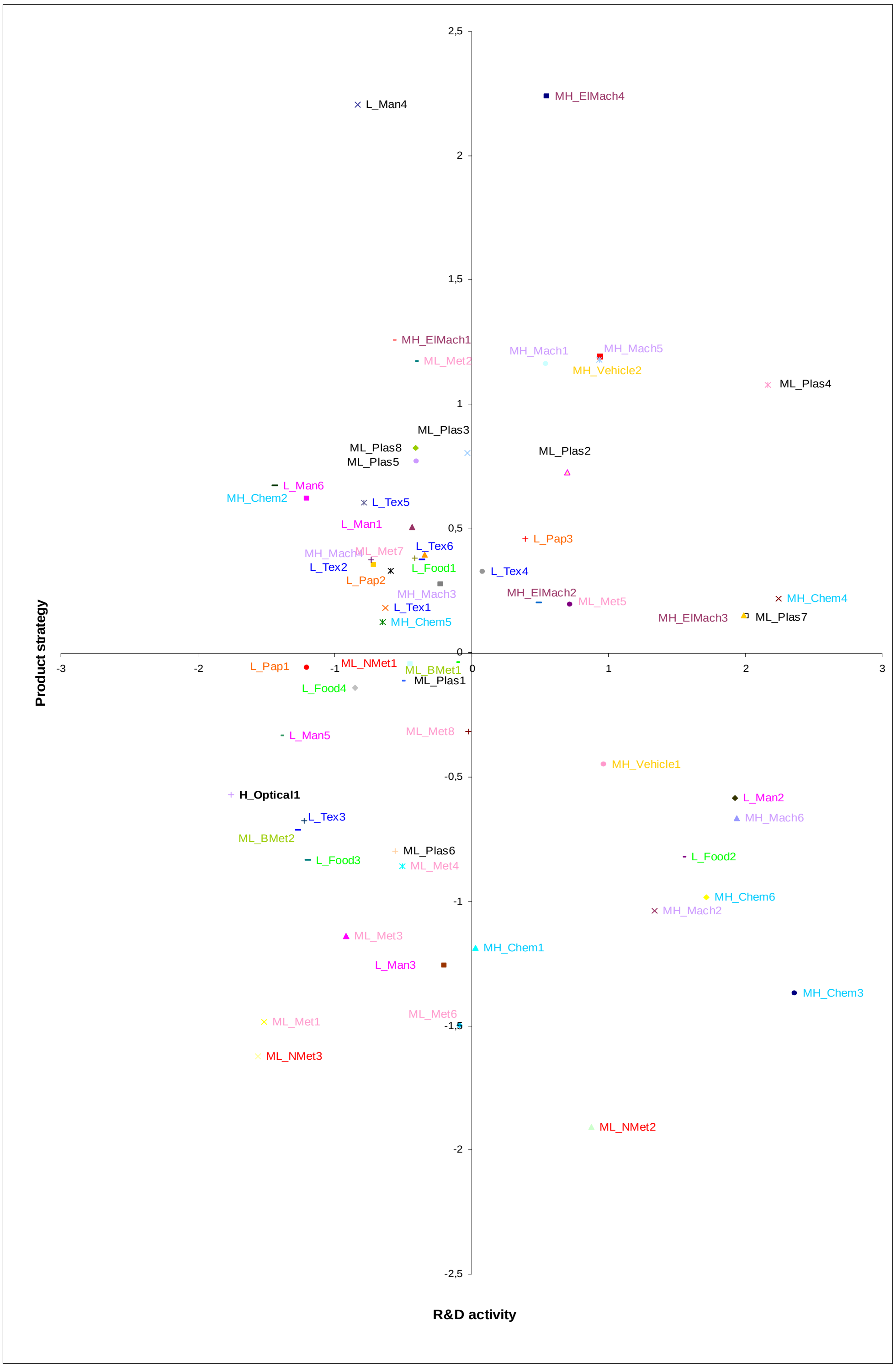


The first dimension, depicted in the horizontal axis, is mainly defined by 5 variables: R&D expenditure, R&D personnel, emphasis on applied research versus development, management attitude towards change, and R&D outsourcing, which is depicted in the opposite, negative part of the horizontal axis. To facilitate communication, we labelled this dimension R&D activity. We must note that R&D outsourcing in our sample does not behave as expected according to the Grinstein and Goldman (2006) classification, since they consider outsourcing to decrease with technological intensity. We find that the higher the indicators of R&D expenditure and personnel, the higher the degree of R&D outsourcing. We argue that this may due to a difference between low and medium and high-tech sectors.

The second dimension, the vertical axis, is mainly defined by three variables: number of new products, ill-defined market needs and management commitment to R&D. Further, the variable, products with short-life cycles also visually composes this second dimension in MDS, although its influence is weaker in the PCA. To simplify communication, we named this dimension product strategy.

Once the dimensions have been interpreted, we can examine the distribution of the 59 firms analysed in the perceptual map in Fig. 2 (where the axes use the labels above resulting order to facilitate understanding).

Figure 2.2: MDS output for 59 firms



The horizontal axis in Fig. 2.2, R&D activity, is the dimension that contains the main proxies used for technological intensity, with the vertical axis separating the positive and negative part of R&D activity. In the positive part there are 22 firms, which are those with higher levels of all variables included in R&D expenditure, personnel, outsourcing, applied research versus development and attitude towards change. We classify these firms as medium-technology firms, and we label the 37 firms remaining on the left of the vertical axis as low technology. This separation, using MDS analysis, discriminates only majorly according to the OECD's technological classification by sectors. Specifically, 32 firms out of 37 in the left part belong to sectors that the OECD classify as low or medium-low, which implies a coincidence of 86,5%. In the right part, labeled medium technology firms, 14 out of 22 belong to medium-high technology sectors, which is a 63,4% coincidence rate. Moreover there are significant deviations in the expected technological ordering. For example, the optical instruments firm, which would be classified as high technology by the OECD, happens to be at the extreme left part of the perceptual map, since their R&D activity indicators are very low. We also observe some firms in medium-high technology sectors with a rating worse than firms classified in low-technology sectors, and vice-versa, firms in typically low-tech rating better than firms in medium-tech sectors.

These comments are based on the decision of grouping firms into the two groups, namely low and medium technology. We contend that there are three important reasons to propose this classification: i) it is the result provided by the MDS analysis, a statistical method that is very useful in capturing distance patterns within firms and variables; ii) the strong - albeit not perfect - concordance with the OECD's basic classification by sectors; and iii) our understanding gained through the survey process, that will be described through the analysis of groups in Section 4.2.

The importance of the second dimension causes firms to differentiate vertically in the perceptual map, as can be seen in Fig. 2. The statistical divisory line is the horizontal axis, separating 32 firms above the axis, and 27 below. Firms above have higher rates for the variables labelled product strategy: they launch more new products on average than firms below the horizontal axis, they have a shorter life cycle, they state to create market needs more than the ones below, their management commitment to R&D is higher, they use more cross functional teams, and they face competition which is more product driven.

2.4.2. Technological patterns

The importance of the second dimension reveals a richer nature of technological intensity that is not captured with single indicators, not even with the widely used R&D indicators, such as expenditure or personnel. It therefore uncovers a non-unidimensional characterisation of technological intensity and patterns. Specifically, data reveals a second important dimension, that we call product strategy. Grinstein and Goldman (2006) also find two relevant dimensions in MDS that share some commonalities with our findings. Thus, we propose that firms are classified using the two dimensions found, R&D activity and product strategy. This gives four groups, whose characteristics resemble to a certain extent those proposed by Pavitt (1984), presented in Section 2.1. For this reason we will borrow the names proposed by Pavitt. Our groups will be referred to as: medium technology specialised suppliers, medium technology science-based, low technology supplier-dominated, and low technology scale-intensive.

Table 2.3: Patterns of low and medium technological intensity

	MedTech 1 Specialised suppliers	**MedTech 2 Science-based**	**LowTech3 Supplier dominated**	**LowTech 4 Scale intensive**
R&D activity and technological characteristics				
R&D activity Expenditure Personnel Outsourcing (external R&D) Applied research vs. development Number of R&D contracts	 High High Medium Applied research Medium	 High Medium high High Applied or basic research High	 Low Medium low Inexistent Development Inexistent	 Low Low Mainly inexistent Development Inexistent
Technological positioning	Leader	Leader	Mixed (leader, follower, niche)	Niche or undefined
Main source of ideas	External (customers, markets)	External (customers, markets)	Internal (management and technical personnel)	External (customers, markets)
Knowledge and technology acquisition	Purchasing machinery	Balanced sources: Purchasing machinery, outsourcing R&D including PRI, alliances	Purchasing machinery	Purchasing machinery
Balance product/process	Product	Mostly Product	Product / Process	Process / Product
Product and market characteristics				
Product strategy Number of new products Short life cycle Market needs Product-driven competition Technology-driven customers	 High Short Create market needs Product-driven High	 Low Long Create and follow market needs Product and price driven High	 High Short Create and follow market needs Product-driven High	 Low Long Follow customer requests Product and price driven High
Importance of design	Average	Average	High	Low
Export orientation	Average	Average	High	Low
Strategic and organizational characteristics				
Key success factors	Innovation Quality	Strategic management Internationalization	Innovation Quality	Productivity Quality
Importance of R&D cooperation	Mostly yes	Yes	No	No
Impact of innovation	Open new markets	Open new markets	Increase sales in current markets	Increase sales in current markets
Management commitment to R&D	High	High	High	Low
Management attitude towards change	Pro-change	Pro-change	Few changes	Few changes
Cross functional teams	Slightly more used	Used	Slightly more used	Used
Incentive systems	Frequently used	Not frequently used	Not frequently used	Not frequently used
Age and size	Young and Small	Old and Big	Average	Average
Mostly represented sectors	Electrical machinery Plastic Machinery	Chemical Machinery	Textile Plastic Manufacturing	Metal Basic metal Non metal minerals

Group 1: Medium technology specialised suppliers

Firms depicted in this group show high R&D activity, in terms of expenditure, personnel, management commitment, outsourcing and applied research orientation. Their strategic focus is innovation and quality, and most of them are technological leaders. They perceive innovation as a means of opening new markets. For these firms, internal R&D is important and their main source of ideas is external, to make product innovations, that clearly dominate over process innovation (70% over 30%, on average). They appropriate from patenting more than the other groups (more than 60% of firms use patenting usually), and they are also more active and conscious of technology transfer by means of licences and assistance. They also obtain part of their technology from purchasing machinery. Their competition is product-driven (performance, features) and they tend to launch an important number of new products with a short life cycle. Their management is proactive in creating market needs rather than following customer requests, and in promoting change and using organizational systems such as cross-functional teams and incentive systems. They also believe in cooperation and are the second group in R&D contracts, after group 2. They are the youngest group in our sample and contain the smallest firms. The most represented are the electrical machinery and plastic sectors.

Within the limits of the available information, this group resembles the specialised suppliers group in Pavitt's taxonomy, although it is not a compact group, as it is observable in the first quadrant of Fig. 2. A large percentage of the firms in the group do not fall so neatly into the category since their R&D activity is more reduced and their outsourcing levels and attitude different. Their features will be close to the ones of group 3, in the left-hand quadrant, Low technology, supplier dominated, described later.

This group also shares some similarities with its homologue in Souitaris (2002), in what concerns to the high growth rate and exporting, the use of training and incentives, and it has high levels of many of the variables that Souitaris included in his multi-indicator of innovation. The comparison with the findings of de Jong and Marsili (2006) also presents some common traits, although we do not test for the openness of the firms.

Group 2: Medium tecnology science-based

In this group there are 9 firms of various industrial sectors, with the most representation from the chemical sector. They are strong in R&D activity, internal and external, which consists of applied research and even some basic research. They find cooperation important and all firms in the group consistently held a number of R&D cooperation contracts. They are strongly positioned technologically in their sectors, and are the second group regarding patenting activity (more than 50%). The main sources of ideas are external, from customers and markets, and they balance several types of external technology acquisition: purchasing machinery, outsourcing R&D including PRI, and alliances with other firms. They focus mainly on product innovation, and sometimes create market needs. Their customers are sensitive to product performance and to other variables such as price. Their key success factors are related more to the overall strategy than to innovation or productivity, and they use innovation to open new markets. They are older than other firms and bigger; they are proactive to change but organizational instruments such as incentive systems or cross-functional teams are, although frequent, not always used.

This group resembles Pavitt's science-based type in the features that we are able to describe, except that firms in electrical and electronic sectors in our sample do not cluster in this group. They also share some characteristics with Souitaris (2002), particularly in depending upon technology-related variables, and learning from customers.

Group 3: Low technology supplier dominated

This group contains firms from a variety of sectors, but those most represented are textile, plastic and other manufacturing. They are weak in internal R&D activity, and do more product development than applied research, with a low patenting activity. They obtain technology from suppliers, and their group is the most oriented towards process innovation. They are product push in the market, but through design changes, as opposed to technological innovation. Although customers are considered as sources of ideas for innovation, internal sources of ideas (management and technical staff) are rated higher, probably to deliver process innovations with purchased technology and design changes to their products. They consider R&D cooperation not to be important and do not have R&D contracts at all. They face cost-cutting pressures in very competitive markets, and respond through (incremental) product innovation and quality to avoid strong price-oriented competition and maintain sales in their markets.

On the whole, with the available information, we judge that they resemble strongly Pavitt's type of supplier dominated firms, except for that most of them are unwilling to learn from PRI or other firms. The importance of the competitive environment, technology strategy and internal coordination is found like in Souitaris (2002). Similar to de Jong and Marsili (2006) they are dependent on suppliers in technology but, in contrast, not in innovation.

Group 4: Low technology scale intensive

Firms in this group have low R&D activity and mainly focus on development. Similarly to group 3, their balance of innovations is more process oriented than groups 1 and 2. They, on the most part, do not use patenting. Management commitment to change and R&D is low, and they do not find R&D cooperation important and, consistently, do not hold cooperation contracts. Their main source of ideas is external, through customers and markets, and they obtain technology mainly by purchasing machinery. Their markets are product and price-driven, and they follow customer needs, generally counting on closer customer relationships. Productivity is a key success factor and they innovate to increase sales in current markets, by pursuing quality and productivity, revealing the importance of cost-cutting.

This characterisation shares similarities with Pavitt's scale-intensive sectors, except mainly for the importance of firm size. Our results are obtained from SME firms, of various sizes, with only 7 out of 18 having more than 100 workers. In comparison with the homologue group in Souitaris (2002), our group points to productivity and quality as being more important than fund raising.

2.4.3. R&D cooperation

The results of analysing the dimensions of technological patterns, presented in Section 2.4, show that R&D outsourcing was included in the first dimension considered, together with other R&D indicators, namely R&D expenditure, R&D personnel, and applied research versus development. For MDS analysis we used the percentage of external R&D provided by executives. But additionally we asked two more questions on cooperation: whether they considered that R&D cooperation was needed to compete, and the number of R&D contracts subscribed to during the previous 3 years. The answers obtained were consistent with the previous percentage revealed by managers. We have already summarised this information in Table 2.3 in Section 2.4.2, and have used it to present the technological features of each group of firms.

It is important to note that firms in the Low technology (LT) group (37 firms) have very clear results about R&D outsourcing and cooperation: i) they have no external R&D, except for five firms; ii) they say they do not need R&D cooperation to compete, except for four firms; and iii) they have no contract for R&D cooperation, except for 4 cases.

The 37 firms in the LT group, were high-performing even in the absence of high R&D activity, including R&D formal cooperation. Thus, their success should be due to other success factors. Pavitt (1984) also provides some clues to this situation. These firms face competition, customers, suppliers, and technology, that allows them to survive and further grow by acquiring state-of-the art technology from suppliers and provide newly designed products to the market, such as the case of group 3 (LT supplier dominated firms). In the case of group 4, they mainly use engineering (not R&D) teams to drive and enhance productivity with technology purchased from suppliers (LT scale-intensive firms), and also probably profit from some labour cost advantage within the Spanish labour structure. Further, we could guess that informal cooperation was taking place with some suppliers, although this was not explicitly corroborated by the firms themselves.

The lack of trust placed on the importance of R&D cooperation, together with the low R&D activity profile, made it difficult to engage executives to talk about specific barriers to R&D cooperation. We could consider that the low R&D activity and the management attitude towards R&D cooperation was preventing cooperation, acting somehow as an absolute barrier to cooperation.

On the other hand, for firms with higher R&D activity (groups 1 and 2), we found mostly that cooperation was considered important, and that many firms engaged in R&D contracts. Specifically, all firms in group 2 had contracts and half of the firms in group 1, the ones with higher R&D activity. Thus, for these firms the formerly mentioned absolute barriers did not exist: they have a higher R&D activity and their managers believe in the benefits of R&D cooperation.

Of the 22 firms with medium technology, belonging to groups 1 and 2, we obtained responses about the barriers to cooperation for 18 firms, for general barriers, and 17 firms for barriers with university as a partner. The average results are presented in Table 2.4.

Table 2.4: Barriers to cooperation

Barriers to cooperation in general

	Type	TOTAL*	MT specialised supliers*	MT science-based*
Lack of internal R&D	Intra (firm)	4,56	3,89	5,22
Difficult knowledge exploitation	Intra (firm)	4,06	3,56	4,56
Difficult knowledge absorption	Intra (firm)	4,00	5,33	2,67
Lack of technological surveillance	Intra (firm)	4,00	3,78	4,22
Complex and expensive management	Inter (partners)	3,61	2,11	5,11
Insufficient size	Intra (firm)	3,50	2,67	4,33
Underused internal R&D	Intra (firm)	3,17	2,67	3,67
Excessive legislation, regulations and bureaucracy	Inter (partners)	3,17	3,22	3,11
System and modus operandi differences	Inter (partners)	2,83	2,56	3,11
Unsatisfactory previous experiences	Inter (partners)	2,78	2,00	3,56

N=18

Barriers to cooperation with universities

	Type	TOTAL*	MT specialised supliers*	MT science-based*
Unresponsiveness to industry needs	Intra (university)	5,18	6,88	3,67
Inapplicability of projects	Intra (university)	3,41	4,63	2,33
Cultural and modus operandi differences	Inter (university - firm)	3,00	2,75	3,22
Lack of trust for diffusion	Inter (university - firm)	2,59	2,25	2,89
Lack of technical and scientific resources	Intra (university)	2,53	2,50	2,56
Excessive legislation, regulations and bureaucracy	Inter (university - firm)	2,35	2,50	2,22
Results sharing and use	Inter (university - firm)	2,18	2,13	2,22
Unsatisfactory previous experiences	Inter (university - firm)	2,18	3,13	1,33
Academics' task/work inefficiency	Intra (university)	1,71	2,25	1,22
Geographical distance	Inter (university - firm)	1,00	0,25	1,67

N=17

* Average ratings for barriers to cooperation ranging from 0 meaning not a barrier, 5 for a surmountable barrier, to 10 for an insurmountable barrier.

The first observation for the pooled results for general barriers is that all barriers are below 5, which implies they have only a moderate effect on cooperation. Secondly, there are differences between groups in intensity of barriers and rankings. For group 1, MT specialised suppliers, the main barrier is clearly the difficult knowledge absorption, which surpasses the intensity of 5, followed by three other internal barriers: the lack of internal R&D to cooperate, the lack of technological surveillance, and the difficult knowledge exploitation. For group 2, MT science-based, there are also two barriers with intensity above 5, the first coincides with group 1, the lack of internal R&D, but the second is an inter-firm barrier, complex and expensive management.

These results indicate that firms with more experience in R&D contracts find inter-partner barriers more important than internal barriers, probably also because they have (on average) a higher R&D activity than firms in group 1. Firms with medium but lower R&D activity, find more intra-firm problems when trying to benefit from R&D cooperation.

The results for barriers with universities show there is an overall outstanding barrier: university's unresponsiveness to industry needs, with an average rate over 5. The other outstanding barriers are also due to the university (inapplicability of the projects and cultural and modus operandi differences). For group 1, with less cooperation, university unresponsiveness acts as a difficult to overcome barrier (rated almost 7). Firms in group 2, that have more cooperation tend to rate barriers lower. This result is in line with Mora et al. (2004) who found that previous links enhance the probability to engage in cooperation.

2.5. Discussion of findings

2.5.1. The multidimensional approach and R&D cooperation

This paper has focused on investigating the relationship between the technological pattern of firms and R&D cooperation, specifically the barriers encountered to engage in R&D cooperation. We work with a sample of 59 fast-growing SMEs that are classified as LMT firms. The initial assumption was that these fast-growing firms with LMT would rely on external R&D to be successful, since they have a limited internal R&D capability. Our findings do not corroborate this general assumption, since they uncover a more complex conception of R&D intensity, the importance of other sources of technology rather than R&D cooperation, and that R&D may not be a necessary key success factor for some technological or strategic patterns.

We first noted that high performance is not associated with high R&D outsourcing or cooperation. Only 23 firms out of 59 revealed some external R&D, and only 18 firms had R&D contracts in the previous three years. Secondly, we can not explain this behaviour by using industry belonging or a single technological indicator (such as R&D expenditure, or personnel). This paper shows that a multidimensional analysis of technological intensity provides a better classification of firms, dividing firms into distinct groups and visualizing the necessary conditions to engage in R&D cooperation. We find that R&D cooperation is found above a certain level of R&D activity, which is the first dimension found, and that is a composite of several indicators.

The results of Multidimensional Scaling reveal that two dimensions are important to account for the richness of data about technological intensity, and that these two dimensions integrate several R&D indicators and other proxies of technological features. The two dimensions generate four quadrants that we use to define four groups of firms with different technological features. We analyse these groups and describe their sources of technology acquisition, process and product innovations.

2.5.2. Contributions to academic research

Our contribution is to provide empirical results grounded on extant theory. Findings ought to reflect the richness and diversity of the data, and if possible the ways in which they contradict as well as support conventional thinking. In this way, new theoretical contributions can further be grounded in objective evidence from applied quantitative and qualitative investigations.

The two dimensions found resemble those of Grinstein and Goldman (2006), one related to R&D activity, and the other related to product strategy. In contrast, we do not find a separate dimension for corporate culture, that they obtain from a content analysis. We find that elements of corporate strategy integrate and contribute to the former two dimensions, and thus, reinforce the focus on R&D activity or product strategy. In this way, we contribute to their call for more research on technology firms. Another distinctive aspect is that we find a clear role for R&D outsourcing in differentiating firms between medium and low technology, and clarifying the difference between groups. In contrast, Grinstein and Goldman did not include outsourcing in their analysis because it had an outlier behaviour in their smaller sample. Further, in their theoretical analysis they consider that outsourcing decreases with technological intensity. In our sample of LMT firms, the results show that the higher the indicators of R&D expenditure and personnel, the higher the degree of R&D outsourcing. This may be a difference between LMT sectors and high-tech sectors. For LMT, R&D outsourcing is inexistent or low with low levels of internal R&D, and increases with more internal R&D. An explanation for this finding is that firms with low technological intensity can not engage or absorb the benefits of R&D outsourcing, because a certain minimum internal R&D is needed to engage in satisfactory outsourcing. The evidence for this is that firms perceive the main barriers to cooperation to be the lack of internal R&D and absorption difficulties. This explains that medium technology firms engage in cooperation while firms in the low technology groups do not. The monotonicity may change for the high-tech industries where the internal R&D capacity can compensate for, and reduce levels of R&D outsourcing (e.g. Freel, 2003).

The four groups we define with MDS analysis show similarities with Pavitt's (1984) taxonomy, which is not surprising since he also studied the manufacturing industry. His seminal work has also been supported by others (e.g. Acha, Marsili and Nelson, 2004; Souitaris, 2002; de Jong and Marsili, 2006). However, we must note that our methods, data availability, and sample are different. We use in-depth interviews to capture data, our sample comes from a Spanish region, and focuses only high-performing SMEs. This may further suggest that Pavitt's taxonomy reflects best practices. However, we find that although these technological patterns may represent best practice, they do not apply directly to sectors. While Pavitt (1984) intended to explain the diversity between sectors, we find and intend to explain diversity within sectors. In particular, except for firms belonging to metal-related sectors, we found that firms in other sectors spread significantly across the four possible groups, indicating that the technological pattern is not strongly conditioned by the sector, rather a strategic choice of the firm.

We have used Grinstein and Goldman's (2006) characterisation to gauge the dimensions underlying the technological intensity of firms, but further we use the dimensions found to classify firms into groups of technological profiles. In this way, we are able to connect the Grinstein and Goldman (2006) characterisation with the taxonomies literature, particularly with Pavitt's (1984) taxonomy. Hence our paper connects the literature on technological intensity with that on technological patterns. The support we find for both types of approaches reinforces their usefulness and their complementarity. This research shows that taxonomies can be effectively used to map differences in the rates of technological activity, the sources and nature of innovation, with the differences in business strategies of fast-growing SME firms.

In Section 2.2. we illustrated that literature on barriers to R&D cooperation was limited, especially with empirical evidence. Our research contributes to this literature by structuring barriers to cooperation, grouping barriers into intra-firm and inter-partners, and exploring them empirically. As far as we know, there are no explicit attempts to measure the intensity of barriers to cooperation, which will go some way to aiding policy development.

Our findings indicate that firms with low technological intensity have no R&D cooperation. Our explanation is that their low R&D activity and management attitude towards R&D cooperation act as absolute barriers, thus, preventing cooperation. In the absence of these absolute barriers, for firms with a medium technological level, barriers are perceived differently by the two groups engaging in cooperation (MT specialised suppliers and MT science-based). Barriers to cooperation in general are related to intra-firm characteristics, associated to insufficient technological level. For firms with higher technological level, these barriers lose importance, and the inter-partner barriers raise their importance. When the partners for cooperation are universities, executives pointed to weaknesses internal to universities, and mainly their unresponsiveness to industry needs. Fortunately for universities, the opinion improves for firms with more experience in cooperation.

2.5.3. Policy implications

This papers raises again the need to account for the multidimensionality of technological intensity (e.g. Grinstein and Goldman, 2006), and to consider several patterns of technological intensity (e.g. Pavitt, 1984, Tidd et al., 2001, Souitaris, 2002). This means that policy applied to firms according to unidimensional criteria, such as industry belonging or single R&D or technological proxies, may not capture the technological options and requirements of firms, and therefore is more likely to fail. In the case of industry belonging, we find that firms in the same sector do not cluster in a single group, indicating that technological pattern is more a strategic option than an imperative within a sector. Although a sectoral-based classification of technological intensity may mostly classify firms correctly, minor differences can be important. For example, in our case misclassification between sectors and technological intensity was 14% and 35% for the low-technology and medium-technology firms respectively. This leads to conclude that for research and policy purposes using the firm level may be better than considering the industry level.

Governmental agencies and policy bodies are involved in formulating and implementing policies designed to encourage and facilitate the creation, development, and growth of firms. They design regulations, incentives, subsidies, and other schemes to support the health of industries. A better understanding of the multimensionality of technological intensity may allow better design of various policy instruments, and a better fulfillment of goals.

This paper shows the results for LMT firms, and that most of them are not capable of leading in innovation. However, the health of economies depends also on the role of LMT firms, as adopters, customers, or complementors of innovations generated in high-tech sectors. Innovations of high-tech firms are profitable when they are adopted across many sectors, and they are more revolutionary the more LMT firms purchase them, adapt, imitate, and complement them with more innovation. The health of the high-tech sectors depends on being able to serve the needs of LMT firms (Robertson and Patel, 2007).

Innovation diffusion is as important as generation, and should be better promoted by policy makers. For example, through promoting a widespread awareness of new technological possibilities, and thus accelerating the rate of diffusion. This in turn, would act as an incentive for investment in R&D in high-tech firms. Moreover, policies should also promote the upgrading of technologies in LMT sectors. The barriers to improve capabilities, such as cooperating with other firms or PRIs, are dependent on technological patterns. Some firms may only need instruments to facilitate contracting and reduce transaction costs. Others may need to grow the internal R&D function. Their needs are extremely different, and the policies they need should also be different.

According to our findings the main problem for cooperation with universities is that firms perceive universities to be unresponsive to industry needs: it is the most significant barrier and it is graded as having more than moderate importance, probably preventing cooperation on some occasions. The reduction of this barrier is mainly the responsibility of the university, however policy makers can design incentives for universities to better meet the needs of industry. Universities and governmental agencies and policy bodies should work together to reduce this barrier: acting on the activities promoted by universities and policies, and communicating the real benefits of universities for partnering with industry. There are some tools that universities and policy makers are already trying to use: creating specialized research centres and science parks, and also promoting an entrepreneurial culture within academia, facilitating and justifying the implication of universities in the transfer of technology.

The second barrier found is the lack of applicability of the projects partnered with universities, most likely connected with the former barrier. Thus, acting on the connection of universities research capabilities with the real demands of firms, will probably reduce this barrier at the same time.

Although inter-partners barriers were not found to be very important, policy can have a positive influence in the reduction of transaction costs of partnering, such as information, contracting, and reinforcement costs. These partnerships would be more secure if there were clear and specific regulations for them (Montoro and Mora, 2006), to clarify roles, expectations, property rights protection, publishing conditions, and incentives for adherence to terms and conditions.

The co-evolution of science and technology is dependent on the efficient cooperation of industries and research institutions (Nightingale, 2004), and nowadays innovation systems try to optimise the efficiency of public funded research, a large percentage of which goes to the university and similar PRIs. Policy makers also have competences in regulating universities and other PRI, and thus, have the potential to influence the context and incentives to promote technology transfer and progress.

2.5.4. Research limitations and future research

We rely on executives' responses to the technological features of their firms, since they are the most expert people in their firms. This may cause a "self reporting bias". However, our investigation provides some control to this bias in two ways: by questioning with "neutral" questions on a large number of proxies of technological intensity and innovation, and by using the MDS method which is very resistant to a few outlier responses.

This study involves a small sample, in turn providing in-depth information on each firm. However this gives the study only an exploratory contribution, since it is not a representative sample of the population of firms in Catalonia, or for other research settings. For this reason, the results that corroborate existing theory and proposals, represent solid support to the referred literature.

We are also aware of the low incidence of R&D cooperation identified in our sample, and that R&D contracts are not representative of all possible types of research undertakings. This implies that our findings should be interpreted with caution. We do not claim that our results can be generalized, we merely want to report the degree of coincidence of our findings with those reported by other authors working in R&D cooperation, technological classification, and technological taxonomies or patterns. We therefore build constructively on the existing research in this field.

Chapter 3. Strategic attitudes in the global textiles market: the case of a South European cluster

Resum

En els darrers anys la indústria del sector de la del tèxtil i de la confecció (T/C) ha sofert grans canvis que s'ha vist reflectits en reduccions de facturació, pèrdua de llocs de treball i el disminucions de les exportacions. El cas d'Espanya, el cinquè major productor dins l'Europa dels quinze, no és una excepció. La liberalització del mercat amb l'entrada en vigor de l'acord GATT – 1994 (*General Agreement on Tariffs and Trade*) ha provocat una gran reestructuració del sector sobretot amb un gran augment de deslocalitzacions en la producció.

Dins d'aquest context, la promoció de la innovació i la R&D poden ser importants factors de competitivitat. L'objectiu d'aquest treball és analitzar dins d'un clúster del sector del tèxtil i la confecció ubicat a la província de Girona, al nord-est d'Espanya, quins diferents perfils innovadors es troben entre les empreses analitzades per entendre millor les seves actituds innovadores de cares a una futura supervivència dins del mercat global.

Les dades utilitzades provenen de les entrevistes realitzades en profunditat als directius de les empreses analitzades. Els resultats mostren com el subsector al qual pertanyen les empreses té una relació directa amb la seva posició tecnològica i estratègica dins del mercat.

Abstract

In recent years the textile and clothing (T/C) industry in the EU has suffered difficult times, with declines in production and employment and an increase in the trade deficit. The case of Spain, the fifth producer in the EU-15, is no exception. In spite of Spain having lower costs than most of its EU partners, the globalisation of the T/C industry and the liberalisation of the sector brought about by the GATT 1994 agreement have caused important restructuring in the sector, with the critical effects of downsizing and reallocation (delocalisation) of production.

Within such a framework, innovation and R&D are seen as the key issues for competitiveness. We aim to analyse a particular cluster of T/C producers in the province of Girona, in the north-east of Spain. We look at the strategic similarity of the firms in the study and, in particular, whether there are different innovation profiles. We argue that different strategic attitudes and innovation profiles entail different prospects for future survival.

Qualitative and quantitative data were gathered via structured interviews with the top-level management team of each firm. The results show that the subsector in which firms compete influences their strategic and technological positioning.

3.1. Introduction

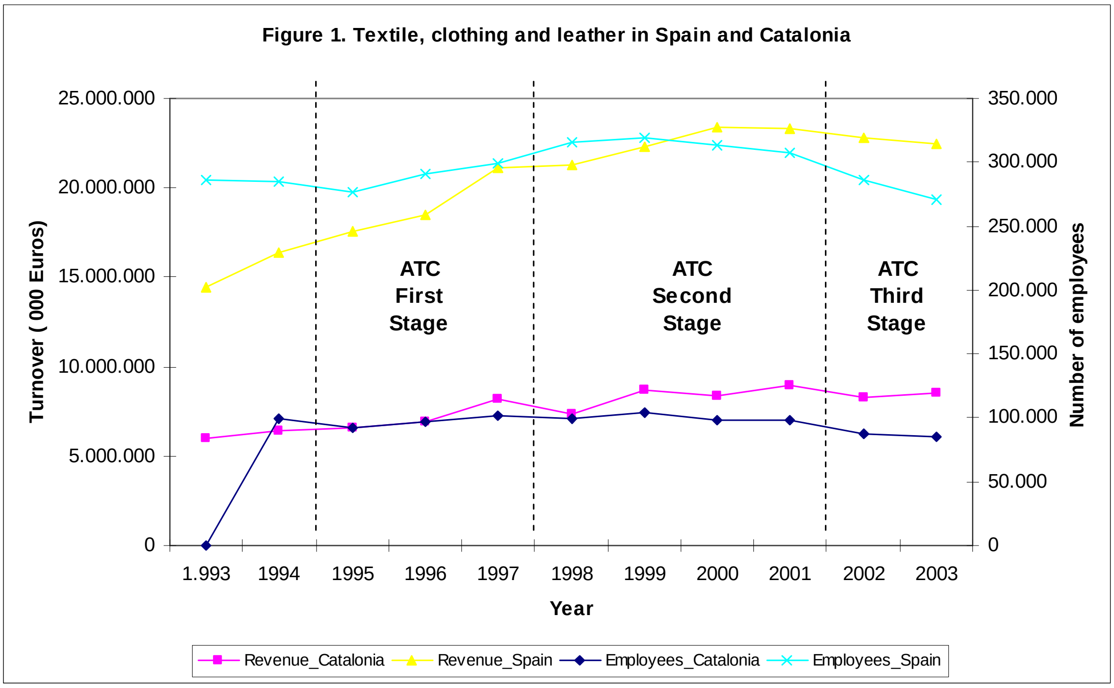
The drivers of change in the textile and clothing (T/C) industry have been multiple and their effects considerable: the liberalisation and globalisation of the industry, with the emergence of important new competitors, technological change, the evolution of production costs and EU integration and enlargement are among the most important. These factors have changed the competitive advantages formerly enjoyed by existing competitors. The cases of Spain, the fifth producer in the EU-15, and of Catalonia, the first textile region in Spain, are no exception. The traditional positioning of T/C producers in Spain was of low-cost production. However, following the entry of new competitors, Spain is no longer a low-cost producer. The sector has suffered pressures to downsize and to reallocate production, especially of labour-intensive work.

The competitive pressure has been greatly influenced by the liberalisation calendar. The Agreement on Textiles and Clothing (ATC) established a ten-year transition period (1995 to 2005), to progressively incorporate products from the list in the Annex of the Agreement (ATC, XXX). The first stage began on 1 January 1995, the second on 1 January 1998, the third on 1 January 2002 and the final one on 1 January 2005 (Wysokinska, 2004).

The effects of liberalisation in Spain

Some basic descriptives of the sector activity in Spain are depicted in Figure 3.1, showing the beginning of the three stages of the liberalisation process. Figure 3.1 represents the time series of revenue for the textile, clothing and leather industry and the evolution of the number of employees, over the 10 years from 1993 to 2003, for the whole country and for the region of Catalonia. The first stage (1995-1997) shows positive trends, especially for Spain, in both revenue and employees. During the second stage (1998-2001), the increase in turnover continues but this period marks the start of a considerable decrease in employment for both the whole of Spain and Catalonia. On the whole, from 1993 to 2003 turnover increases by 56% for Spain and 41% for Catalonia, while employment decreases by 5% and 15% respectively. The figures become worse if the maximum level of employment, achieved in 1999, is taken into account. Job losses from 1999 to 2003 account for 15% in Spain and 18% in Catalonia.

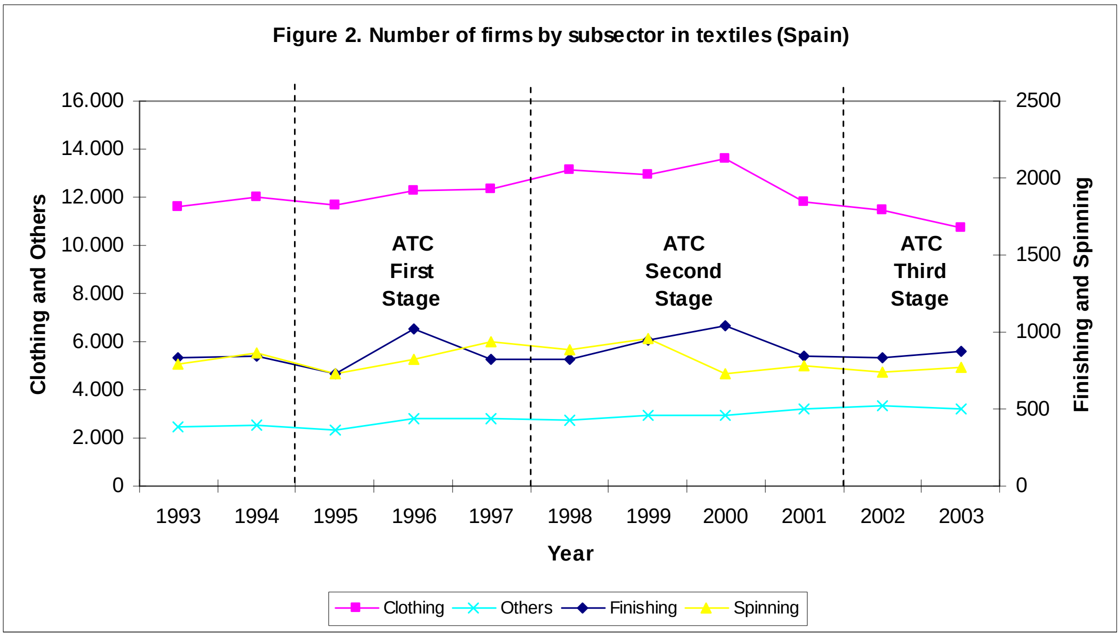
Figure 3.1: Textile, clothing and leather in Spain and Catalonia (revenue and employees)



Source: INE (National Statistics Institute) of Spain.

The number of firms operating in the sector shows a similar trend. Figure 3.2 represents the data for Spain and Catalonia for four groups in the T/C industry: spinning, clothing, finishing and others. The spinning subsector contains those firms dealing with the treatment of raw materials, i.e. the preparation or production of various textile fibres and/or the manufacture of yarns, either natural or man-made. The clothing group includes, in this case, the production of knitted and woven fabrics and the transformation of these fabrics into products such as garments. The finishing group includes those firms which deal with giving fabrics the visual, physical and aesthetic properties which consumers demand, such as bleaching, printing, dyeing, impregnating, coating, plasticising, etc. The others group includes firms which produce textile articles other than for clothing, including carpets, home textiles, technical or industrial textiles, and other remaining types of textile firms.

Figure 3.2: Number of firms by subsector in textiles (Spain)



Source: Own elaboration using data from INE of Spain.

The number of firms in these four groups generally increased for all groups until the second stage of the ATC liberalisation process, reaching a maximum in 1999 or 2000. Since then there has been an important decrease for three groups: 16% for finishing between 2000 and 2003, 21% for clothing in the same period and 19% for spinning between 1999 and 2003. The other textiles group has steadily maintained its increasing trend, with an increase of 28% in number of firms between 1993 and 2003.

In view of the situation in Spain and Catalonia, we wondered how other T/C zones are prepared to face the increased competition of the new liberalised and globalised T/C industry. We therefore aim to analyse the situation of the Girona cluster of the T/C industry. Girona is a province of Catalonia, Spain. Our analysis of the industry focuses on the technological and adaptive profiles of the firms. In particular, we use the strategic types proposed by Miles and Snow (1978a; 1978b) to analyse the different strategic and technological profiles of the firms, discussing the different ways in which the various types of firms face their competitive environments and how this influences their ability to survive in an environment of global competition.

We carried out a qualitative study over a sample of 22 firms in the T/C industry in the province of Girona. To gauge the firms' strategic and technological profiles, we used in-depth interviews to obtain qualitative and quantitative data from their top-level management teams.

The article is organised as follows. In Section 2 we present the background on strategic types which we extend to technological types. In Section 3, we present the empirical process and dimensions that we use to describe the strategic and technological types. The results are analysed in Section 4 and a final section concludes the article.

3.2. Strategic and technological types

Firms' adaptation to a dynamic competitive environment

The more an industry is changing, and the more competitive it is, the more important it becomes for a firm to align all managerial processes with its environment. The recent evolution of the T/C industry is a good example of this. Miles and Snow (1978a) proposed that organisations tend to follow a certain pattern of behaviour to align with their environment. This framework is still used and re-examined, as in DeSarbo et al. (2005). Miles and Snow considered that this "adaptive cycle" involved three key strategic problem sets: i) the entrepreneurial problem set, which focuses on identifying new opportunities and thus defines a firm's products, services and markets; ii) the engineering problem set, which contains the choice of technologies to be used in production and distribution of the chosen products and services; and iii) the administrative problem set, where a firm must develop appropriate structures and processes to use technology to create products and services to deliver to the market and also facilitate the innovative activity needed to maintain future adaptive capacity.

Such a framework considers that firms choose the environment in which they operate by means of their choices of markets, products, technologies, scale of operations, etc. These choices are strongly constrained by the firm’s extant knowledge of alternative organisational forms and managers’ beliefs about what the firm can do, or about how people can and should be motivated. This causes inertia in the firm's patterns of adaptation. These enduring patterns of adaptive behaviour can be simplified into four strategic types: prospectors, defenders, analysers and reactors. The four types differ in how they perceive the environment and in how they see and face the three problem sets outlined above: the entrepreneurial problem, the engineering problem and the administrative problem.

Four different strategic attitudes towards adaptation: the Miles and Snow typology

Miles and Snow (1978b) also referred to **prospectors** as industry “designers”. They are proactive in the identification and exploitation of new opportunities. They aim to be “first-to-the-market” with new products or services, and they stand out in their ability to develop innovative technologies and products. Prospectors are able to perceive that the environment is dynamic and uncertain and prepare their firms to be flexible in order to cope with this environment. They achieve this by being product or market oriented, allowing a loose structure and low levels of division of labour, formalisation and centralisation.

By contrast, **defenders** perceive the environment to be stable and certain, or, alternatively, try to find and shape these stable environments. They usually offer a limited, stable product line, concentrating on a few segments of the market, which they try to serve exceptionally well. External stability allows them to concentrate on maintaining their marketing and financial position. With strict control of their operations aimed at internal efficiency, they compete primarily on the basis of cost and/or value. They use a functional organisational form, an extensive division of labour, high formalisation and high centralisation.

Analysers can be considered a hybrid type, encompassing features of both prospectors and defenders. Their products are fairly stable in certain markets, where they act as defenders with tight control and in search of efficiency. But they emulate prospectors in their new ventures, allowing flexibility and loose control for new products and markets. They pursue a "second-in" strategy, imitating and improving upon the product offerings of their competitors: the adoption of new ideas and innovations comes only after careful analysis. The strength of analysers lies in their ability to follow (imitate) prospectors while maintaining efficiency in most of their operations.

Reactors are oriented and organised to respond to the short-term problems or pressures of the marketplace by taking few risks. They lack a systematic way of facing changes in a competitive environment. They lack consistency and proactiveness in their strategy and are expected to perform poorly, as their strategic behaviour is weak. The survival of reactors depends mainly on the imperfections of the market.

The strategic type to succeed is contingent to the dynamism of the environment

The success of the four different strategic types depends on the competitive environment that firms face. A stable environment would reward defenders, who can achieve lower costs than prospectors and analysers, because a focus only on internal efficiency would be the most efficient response to an immobile environment (in terms of demand, technology, competitors, etc.). In the opposite situation of a dynamic and uncertain environment, the firms' results will depend on how their products match the requirements of this evolving environment. In this case the prospector would be the most appropriate strategic type, because it is the best at seeking to align with the characteristics of the environment. The analysers would follow and the defender would have an inadequate strategy if segments are not as stable as they assume. In any of both extreme worlds, the reactor strategy is not to be recommended. Some empirical support for this hypothesis on the effect of strategic type on performance is found in Parnell and Wright (1993), and in Dvir, Segev and Shenhar (1993), who look at the short and long term performance effects of the strategic types.

Technological strategy of the four strategic types

This proposal of four strategic types rests on the assumption that firms need to change in order to maintain their competitiveness in changing environments. The dynamic character of markets is nowadays indisputable. Further, changes in the firm are associated with innovation, mainly centred around technological innovation, in either products or processes. Thus, strategic attitude translates into a particular technological attitude or positioning for each firm.

The prospector's attitude towards identifying and exploiting new opportunities is associated with pursuing an outstanding technological position, such as becoming a technological leader or technological challenger, competing to be the first in launching new products or using new processes.

The defender's decision to focus on internal efficiency can be successful in stable segments, which are bound to be limited. Thus, these firms could be considered as technological niche seekers, targeting the specific requirements of these segments, which will have different needs from other similar, but more hypercompetitive and probably broader, segments.

The technological strategy and positioning of analysers will also be intermediate. Their strategic attitude means that they prefer not to be the first in launching new products, and their focus on the efficiency of established lines gives them a disadvantage in time-to-market. In general, they are expected to be technological followers, trying to trail the leader. However they may use a different technological strategy in their various (old and new) markets.

The technological strategy of a reactor is non-existent. Their lack of consistency in strategic attitude will cause them to be inconsistent leaders, neither niche seekers nor followers.

Table 3.1: Strategic and technological types

Strategic Type	**Technological type**
Prospectors	Technological leader or challenger (innovators)
Defenders	Technological niche seeker
Analysers	Technological follower
Reactors	Inconsistent technological strategy

3.3. Evaluating strategic and technological types: the case of Girona

Our empirical research is based on a sample of 22 firms in the textile and clothing (T/C) sector located in the province of Girona (Spain). The sample was chosen to include firms representing the main subsectors and also the largest in terms of turnover. The distribution by subsectors and brief descriptions are presented in Table 3.2. The five firms in the fibre spinning group are on average the largest in number of employees and turnover, with a long tradition in the sector and an important export orientation. In the cotton spinning group we find the older regional firms of the sector, eight firms with a similar export profile but fewer employees and a considerably lower turnover. In the finishing subsector there are five firms with a smaller number of employees but a larger turnover than firms in the cotton spinning group. The four firms in the clothing group are the smallest, newest and more oriented to the internal Spanish market.

Table 3.2: Descriptive statistics of the sample

Subsector	Number of firms	Average Number of Employees	Average Turnover (€m)	Average Export (%)	Average age of Firm
Cotton spinning	8	99	12.5	71.6	80
Fibre spinning	5	262	46.4	71.6	69
Finishing	5	50	17.6	57.5	60
Clothing	4	29	1.3	42.5	27
Total	22				

Source: Data obtained in interviews, figures for end of 2003.

We used structured interviews to obtain the data and questions were answered by managers of the firms, with positions ranging from general managers to functional managers, in most cases from the production or R&D department.

In the questionnaire, we used seven dimensions to gauge the strategic and technological type:

1) Current strategic focus
2) Desired strategic focus
3) R&D intensity
4) R&D type
5) R&D outsourcing or collaboration
6) Specific technological needs
7) General technological needs

Current strategic focus

To capture the first dimension, the current strategic focus factor, we used an open question asking which were the present three key success factors (KSFs) for the firm. We expected prospectors to highlight innovation and identification of new opportunities as a central KSF, while defenders would refer to productivity, efficiency, or customer service. Analysers should respond that the KSFs depend on the line of business and correctly identify some of the KSFs for prospectors in the case of new ventures, and defenders' KSFs for established products. The last category, reactors, would refer to short-term and non-strategic objectives.

Desired strategic focus

For the second dimension, the desired strategic focus, we used a closed question asking each firm to rank the three main factors that would give it a competitive advantage in its markets. Firms could choose among strategic management capabilities, productivity, quality, innovation, finance, human resources, commercialisation, internationalisation and a selection of others with more specific key success factors. The firms that identified innovation as an outstanding KSF were identifying the prospector type. The firms that identified productivity, commercialisation and internationalisation, would be aiming to be defenders. The cases that combined the two views were adopting the analyser attitude.

R&D intensity and R&D type

R&D intensity was evaluated according to whether or not the firm had an established R&D department, a systematic research activity, and the volume and nature of its R&D. The type of R&D was identified by the distribution of R&D efforts between product or process innovation. Prospectors should have high and systematic R&D and favour product innovation to target new needs. Defenders could maintain a lower level of R&D intensity, oriented more towards process innovation in order to reduce costs or adapt the product to the customer. Analysers would combine the two previous profiles, while reactors would show an unsystematic and low level of R&D.

R&D outsourcing or collaboration

The attitude towards outsourcing R&D was also considered important, in order to describe its strategic and technological type. Companies were asked to what extent they used collaboration or outsourcing in R&D. We consider that a tendency towards using external R&D support would be high for prospectors, intermediate for analysers, low for defenders and non-existent for reactors.

Specific technological needs

The firms were asked to identify their main specific technological needs, which they considered could be outsourced. Given the committed attitude of prospectors towards innovation, we expected them to suggest that some part of their research on new products could be externalised. For defenders, on the other hand, we would expect research on more efficient processes to be more consistent with their desire to reduce costs or improve customer service. Analysers would show a hybrid of the two previous types, while reactors would have difficulty in thinking about long term technological needs.

General technological needs

To complement the previous question regarding external technological support, we added a closed question on the importance of the different possible types of support to a firm. The options covered four categories: product development support, process development support, consultancy and human resources development. The profile of prospectors is consistent with the first type of demand, for product development support. Defenders fit better into the second type of demand, and analysers would show a mixed position. Reactors would tend to give importance to consultancy, to compensate for their short term focus.

3.4. Results

Each of the 22 firms analysed was evaluated across these seven dimensions. Each firm obtained a mark which classified the firm into one of the four types for each dimension. To obtain the dominant type for each firm, we added up the marks for each of the four types. The dominant type is the one that obtains the highest percentage of marks. Table 3.3 shows the resulting dominant types, aggregated by subsector in the T/C industry: cotton spinning (CS), fibre spinning (FS), finishing (FI) and clothing (CL). Most of the firms, 12 cases, are classified as defenders and half of those belong to the CS subsector. Seven cases are considered analysers, these coming mainly from the FS group. The other types are less important in terms of number of firms. Only two firms are prospectors, one from the FS group and the other from the FI group. Finally, only one firm, belonging to the CL group, is classified as a reactor.

Table 3.3: Strategic types by subsector

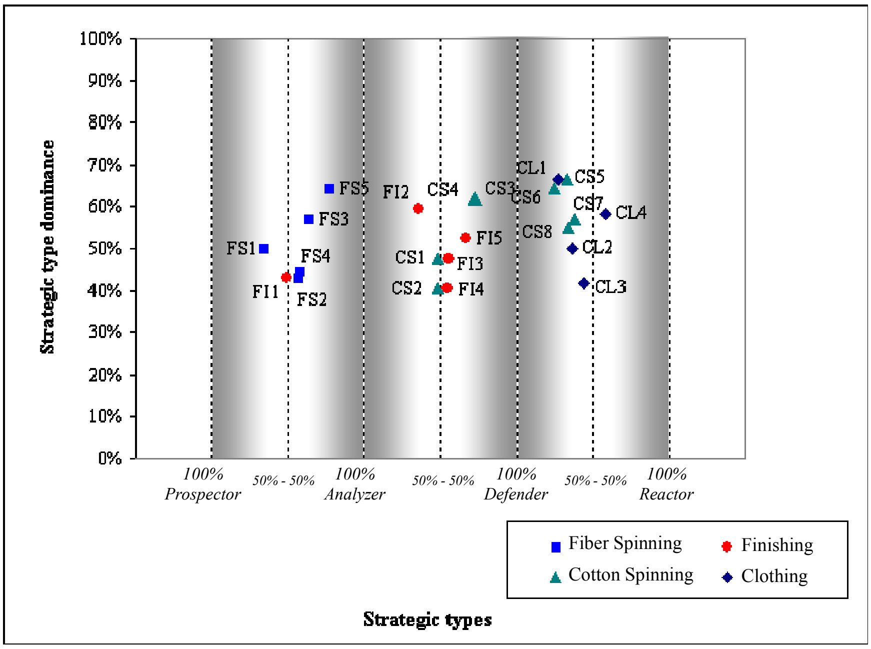
Subsector	Total number of firms	Prospector	Analyser	Defender	Reactor
Cotton spinning	8	-	2	6	-
Fibre spinning	5	1	4	-	-
Finishing	5	1	1	3	-
Clothing	4	-	-	3	1
Total	22	2	7	12	1

Source: Own elaboration.

These results show that the firms in three of the subsectors are following an important uniform strategic type. Particularly, most firms in the cotton spinning and clothing subsectors are defenders, while most of those in fibre spinning are analysers. The finishing subsector presents greater strategic heterogeneity.

A closer examination of the results reveals that the dominant type represents between 40% and 67% of the total marks. This raises the question of whether there is a secondary type which would convey relevant information on the strategic positioning of the firms. To consider this possibility, we analysed the second most important strategic type for each firm. The results are presented in Figure 3.3.

Figure 3.3: Strategic types in a continuum



Source: Own elaboration

We found that membership to the strategic types could be considered as a continuum, starting in the prospector type, followed by the analyser, the defender and the reactor. This guides the representation in Figure 3.3, where the horizontal axis represents the positioning of the 22 firms between two adjacent strategic types. The darker zones represent the pure strategic types and the white zones lead to the hybrid areas, where the positioning of a pure-hybrid firm would be 50/50 between two adjacent strategic types. The vertical axis represents the degree of dominance of the main profile, showing the percentage of points obtained by the dominant type. This dominance could reach 100% for a pure prospector, analyser, defender or reactor, although in our sample it only ranges between 40% and 67%.

Figure 3.3 adds to what we learned in Table 3.3, illustrating that many cases show a hybrid position in strategic type and are situated in the 50/50 (white) zones. The clearest hybrid cases between prospector and analyser are the case of FI1, with a slight dominance of the prospector type, and FS2 and FS3 with a slight dominance of the analyser type. There are also clear hybrid cases between analyser and defender, with 2 firms from the cotton spinning group (CS1 and CS2) and 2 firms from the finishing subsector (FI3 and FI4).

If we analyse the distribution of firms in Figure 3.3 by subsector, we observe that the fibre spinning firms are situated more to the left side of the graphic. This indicates that they are the group with a higher prospector profile. At the opposite end, the clothing subsector is the one situated more to the right, indicating its higher reactor profile. We can also appreciate the greater spread for the cotton spinning and finishing subsectors. According to the theory on strategic and technological types, not all competitive environments favour the same strategic type. This means that it may be the case that the prospector or analyser type is more suitable for the fibre spinning subsector, while a defender attitude is better for the cotton spinning subsector. However, we argue that the reactor type should be considered strategically vulnerable.

3.5. Discussion and conclusions

As in all EU countries, the T/C sector in Spain faces a difficult situation in terms of maintaining competitiveness. This article has addressed the strategic and technological types, in order to evaluate the strategic similarities or differences among the firms of a T/C cluster in Girona, Spain. An approach like this can contribute to the understanding of key issues for companies' survival in the mid term. The technological types used share some features with the contribution of Wysokinska (2003) on marketing strategies, but our approach gives more emphasis to dynamism by studying the adaptive capacity of the firm and its attitude towards adaptation and change.

We carried out a qualitative and quantitative study to classify firms into four types: prospector, defender, analyser and reactor. We have argued that strategic types could be related to technological types. The classification of firms was made by analysing seven dimensions related to strategy and technology: current strategic focus, desired strategic focus, R&D intensity, R&D type, R&D outsourcing or collaboration, specific technological needs and general technological needs. Our findings show the dominant strategic types for the different subsectors in the T/C cluster that we analysed. First, we find that the most generalised type is the defender, with more than half of the firms falling into this group. By subsectors, we find that the majority of clothing and cotton spinning firms are defenders, while fibre spinning firms are analysers. The finishing group is more heterogeneous and does not show such a clear result.

A more detailed analysis reveals that, apart from dominant strategic type, the second placed type was also relevant. This analysis revealed that some cases were better classified as hybrids of two strategic types. The data also revealed that our results could be presented in a continuum of strategic types, starting with the prospector and continuing with the analyser, defender and, finally, reactor. This result is actually consistent with the theoretical definitions, from the more proactive type (prospector), to the protective attitude (defender), with the mixed attitude in the middle (analyser), and finally the more strategically passive attitude (reactor).

By subsectors, this last analysis revealed that the most prospective attitude was held by the fibre spinning subsector, and the most reactive attitude was held by the clothing group.

Strategic implications for firms: are we fit for competition?

Theory and empirical research confirm that a different strategic attitude is needed to face a different competitive environment. Stable environments can be dealt with by means of the defender attitude, with a reduced and stable product range and emphasis on improving processes and better customer service. More hypercompetitive markets need a prospector attitude, exploring new opportunities and struggling to be the first to innovate. Research and innovation are the core of such strategic behaviour. If a firm faces a variety of competitive environments, the hybrid attitude of the analyser encompasses some traits for stable markets and some for new, unstable markets. The reactor strategic type is not advisable in any circumstances.

Our example cluster of 22 Girona firms showed the classification of firms into strategic types. The results for fibre spinning, cotton spinning and clothing were quite consistent across firms within the groups. This reveals the strategic similarity of these firms and probably their adaptation to a different competitive environment. However, it also gives rise to concern about the ability of some of the subsectors to adapt to increasingly competitive environments.

Policy implications: collaboration for success?

If strategic attitude has a relevant influence on a firm or sector's ability to survive, institutions should be concerned about firms' strategic health. We contend that strategic diagnosis of sectors should be a priority for public institutions, to enable them to develop support policies.

This research was part of a wider study on the possible creation of a technological centre to support the T/C cluster in Girona. For this reason a diagnosis of strategic positioning was pertinent, as was an evaluation of the technological needs firms that could benefit from the externalisation of certain technological processes. The research revealed that externalisation of technological tasks was very small and that collaboration between firms provided an opportunity to gain and maintain competitive advantage.

Innovation policies could contribute towards the creation of innovation support infrastructures and promote the development of collaborative projects on design or technology. Such support appears crucial in order to help some defender or analyser companies (mainly SMEs) to move towards the prospector attitude (Figure 3.3). In our opinion, such movement could be viewed as a major challenge to enhance the competitiveness of T/C companies in the Girona region.

Chapter 4. What are the success factors for Spanish textile firms? An exploratory multiple-case study

Resum

L'objectiu d'aquest treball és identificat els trets diferencials de les petites i mitjanes empreses amb èxit, en termes de resultats, dins el sector tèxtil i de la confecció.

El procediments utilitzat és el del múltiple cas de 12 empreses mitjançant informació quantitativa i qualitativa obtinguda a través d'entrevistes en profunditat. A partir de la literatura existent, s'utilitzen quatre dimensions per realitzar l'anàlisi de les empreses: i) generació de coneixement, ii) activitat innovadora, iii) característiques del producte i del mercat i iv) característiques estratègiques.

Els resultats mostres com no hi ha una relació directa entre una major intensitat en R&D i en adquisició de coneixement i l'èxit de l'empresa. La principal diferència es troba en els majors nivells de activitat innovadora ja que la consideren una prioritat estratègica. També de l'anàlisi es desprèn com l'èxit també va associat amb aquelles empreses que aposten per una estratègia de nínxol, proporcionant un alt aproximament al client i complint les seves demandes personalitzades.

Abstract

The objective of this article is to identify differential traits of successful SMEs in comparison to average SME firms in the textile and clothing sector.

The method used is the multiple case-study of 12 firms based on qualitative and quantitative data obtained by means of in-depth interviews. Building on recent academic literature, we use four main dimensions that may explain success: i) knowledge generation (R&D) and acquisition; ii) innovation activity; iii) product and market characteristics and iv) strategic characteristics.

Our results indicate that a higher R&D intensity and knowledge acquisition do not explain success. The main differential characteristic is that successful firms have a higher level of innovation activity, since innovation is their strategic priority, being a result of perceiving the key success factors of their markets differently. From the analysis it also follows that the prevalent strategy of successful firms is the niche strategy, with a demand pull focus, and a high proximity to the customer.

4.1. Introduction

The textile and clothing sector is of a heterogeneous nature, comprising firms producing a wide variety of products from high-tech synthetic yarns to wool fabrics, cotton bed linen to industrial filters, or nappies to high fashion. Behind this diversity of final products there is a multitude of industrial processes, enterprises and market structures. Altogether, the textile and clothing industry shares the challenge to sustain its weight in the European manufacturing industry. According to the latest highlights on the EU-25 (European Communities, 2007a), the general trend can be summarized as "slow growth in global textile trade but fast increasing importance of China". The EU-25 exported textile products for the value of 38 billion EUR in 2005. Meanwhile, imports amounted to roughly double, causing a trade deficit of almost 40 billion EUR. The weight of textile exports was 4% of the value of all EU exports and 7% of all imports; 30% of all EU textile imports in 2005 came from China, followed at a considerable distance by Turkey (14%), India (7%) and Romania (5%). Concerning exports, the USA remained the main EU partner for textile exports (13%), followed by Switzerland (10%) and Romania (8%).

The T/C sector made an investment of €5 billion, and a turnover of €198 billion produced in some 150,000 enterprises that employed more than 2.2 million people. Despite these relevant absolute figures, the industry faces a clear and renowned negative trend. For example, from 2004 to 2005 employment decreased a 6.9%, the number of firms a 6.1%, the turnover a 4.8%, and investment a 3.3%. The textile and clothing industry in Europe is predominantly based on SMEs. Firms of less than 50 employees account for 60% of the workforce in the EU clothing sub-sector and produce almost 50% of value added. In the EU-25, the T/C industry is concentrated in the 5 most populated countries, accounting for about three quarters of EU-25 production of textiles and clothing, i.e. Italy, the UK, France and Germany, followed by Spain (European Commission, 2007b).

4.2. Analysis of the situation: trends and strategies

According to the EU (European Commission, 2007c) there have been four main structural changes in the EU textile and clothing industry: i) radical transformations over the last years, due to a combination of technological changes, evolution of the different production costs and the emergence of important international competitors; ii) a lengthy process of restructuring, modernisation and technological progress during which companies have improved their competitiveness by substantially reducing or ceasing mass production and simple fashion products, to concentrate instead on a wider variety of products with higher value-added; iii) competitiveness retention by sub-contracting, or relocation of production facilities, for labour-intensive activities and iv) global clustering mainly in the Euro-Mediterranean Zone.

In the two most recent Euro-Mediterranean Conferences on the textile and Clothing industry (European Commission, 2007d; 2007e) the assumption was that the competitive advantages of the textiles and clothing sector in the EU are now found in a focus on quality and design, innovation and technology, to produce high value-added products. European products generally have a positive quality mark-up, and the EU industry has a leading role in the development of new products, such as technical textiles. Thus, quality, design, innovation and technology are considered core directions to remain competitive. The main particular recommendations flowing from these conferences are: i) continuing to build a base for sustainable growth through investing into human capital and knowledge, based on research and innovation; ii) thinking globally; iii) maintaining a strong will to transform and improve the capacity to adapt quickly to market developments; iv) focusing on environmental aspects of the activities and valorise the output by greening production; and v) improving image in front of public authorities, the press and the banking sector. The translation of these recommendations into strategies included several ways of management restructuring actively, including business downsizing, repositioning of the own brand, investment in R&D, and training for managers and designers. The implications also pointed to shifting to new production areas such as high-tech products, technical textiles or organic textiles, and the search for new business opportunities in emerging economies.

The aim of the Cairo 2007 Conference's was to establish a cooperation in R&D and innovation between the EU and the Mediterranean partner countries, especially between the research sector and the industry, for the exploitation of the latest research and industrial developments, technology transfer and for co-operating in future innovative efforts.

The case of Spain

In Spain, a South European cluster and member of the Euro-Med, the textile industry seems to be the scenario of extremely opposed business stories. While some big corporations working at the end of the value chain are concentrating success aureoles around them, such as Inditex (Zara) and Mango, the rest of the sector is facing difficulties generated by the progressive liberalization of the sector started in 1995 (Llach et al., 2006).

The determinants of success: R&D, innovation or strategy

However general statistics exist, and they analyse R&D capabilities, innovation capabilities, and the strategic options of the firms, they do not allow relating these constructs with success. This is precisely our aim, to study the possible common characteristics of high performing versus average performing firms. In particular, the contribution of this paper is the analysis of 12 real cases of SMEs to obtain detailed information about their knowledge generation through R&D, their knowledge acquisition, innovation activities, strategic and technological options, by means of in-depth interviews. With this qualitative and quantitative data we explore the association of success to their possible drivers, such as R&D and innovation, which academics and policy-makers generally assume to influence positively in success. In contrast to what extant literature does, we examine the differences between successful SMEs and comparable average SMEs. Thus, we are exploring the common characteristics of high performers in comparison to average performers. Enlarging knowledge on the facts contributing to firms' success and rapid growth is useful in order to understand the way in which organizations should exploit opportunities and face future challenges.

4.3. Research methodology

As argued in Miles and Huberman (1994) the conditions of a need for in-depth understanding, local contextualization, and potential for causal inferences, a qualitative research design is appropriate. Moreover, since we aim at finding the possible differences between successful SMEs and average performing SMEs in the textile sector, the recommended method is the comparative case study research methodology (Eisenhardt, 1989; Lee, 1999; Yin 1989).

4.3.1. Sample selection

The 12 SMEs analysed belong to the textile sector of the Catalan region in Spain. SMEs are the prevalent business form in manufacturing, with firm between 1 and 200 employees being 98% of all manufacturing establishments. Catalonia concentrates 15%

of the population in Spain, generates a quarter of the national industrial GDP, almost one third of Spanish imports, and up to 35% of its high-tech exports.

High-Performing SMEs

The sample of high-performing SMEs contains 6 firms belonging to the textile, clothing and leather industry, which were obtained from a wider sample (59 firms) of high-performing manufacturing firms belonging to all sectors, surveyed in a recent study (Solé et al., 2003), with in-depth interviews on R&D, knowledge, technology and innovation management, carried out in 2002. The definition of success was made in terms of sales growth and sustained profitability, for three consecutive years.

Average-Performing SMEs

The sample of average-performing SMEs was obtained from a subsequent survey on the technological needs of 22 firms in the textile and clothing sector, in order to consider the creation of a technological centre for the textile industry. The survey was carried out in 2005 and identified different technological behaviours associated to the subsector where the firms belonged (Llach et al., 2006).

To carry out the comparative multiple case-studies, we needed to choose 6 cases from the average-performing SMEs, with the best comparable basic characteristics. These were the NACE code, which indicates the type of activity within the industry, and size, measured by the number of employees. Apart from this, both samples were of firms in the same Spanish region, which means that they faced a similar environment. We believe that the time difference between the two surveys that generated the data does not generate any systematic bias in the analysis, since the variables studied are relatively structural, and strategic, and therefore they are likely to be quite persistent in the medium term.

4.3.2. Data collection methods

The method for collecting data during these studies was face-to-face semi-structured interviews with general managers at their workplace. The interview covered the following five areas of interest: i) firm descriptive data; ii) knowledge generation and acquisition; iii) innovation activity; iv) product and market characteristics, and v) strategic characteristics. At the end of the interview, respondents had to fill in a prepared quantitative questionnaire on the main aspects of the former three areas, in order to more objectively capture the perception and assessments of respondents on the areas covered. The quantitative data was collected in a data base and the qualitative information obtained was codified by two researchers to produce a report on each of the cases.

4.3.3. Dimensions and measures

To gather the main general descriptive of firms the questionnaire included the basic measures of size, such as employees and turnover, and also age of the firm and export shares. The other dimensions used to study the patterns of success in these samples of firms, are based on two recent research publications. Firstly, the characterisation of the technological intensity of the firm offered by a recent study (Grinstein and Goldman, 2006), by scanning the literature produces a list of 19 defining characteristics for which firms may show three levels of technological intensity: low, medium and high. They include characteristics on R&D effort, innovation activity, product-market characteristics and organizational variables. Since our sample is composed of SMEs, we can also build on another recent work (De Jong and Marsili, 2006) who elaborate a taxonomy of innovative small firms. Their findings indicate that these firms differ not only in their innovative activities, but also in their business practices and strategies – such as management attitude, planning and external orientation, used to achieve innovation. For this reason, we will include in the analysis the strategic characteristics dimension.

The first dimension that we consider is knowledge generation and acquisition**.** It includes R&D effort, which refers to the amount of resources devoted to research and development activities, considered as a proxy of the internal capability of the firms to generate by themselves new knowledge for innovation. The most commonly used indicators are R&D budget, measured as the share of R&D expenditure over sales, and the human resources dedicated to these activities. The existence of a formal department of R&D also reflects the degree of systematization of R&D.

Although the above-described effort can internally generate knowledge, in complex circumstances and rapid environmental change, external knowledge sources may act as a complement to internal R&D. External knowledge and technology sources include different modalities such as: the acquisition of machinery, equipment, or technology under any form, the recruitment of personnel, or the knowledge obtained from clients, suppliers or other firms. Further, outsourcing and cooperation in R&D can also produce knowledge, whether it comes from contracts with other firms, universities or other research centres.

The second dimension is innovation activity, that embraces the practical use of knowledge to produce new or improved products (product innovation), or use new or improved production or organizational processes (process innovation), including technological and organizational innovations. We assess the innovation intensity of firms by assessing the degree of systematization in conducting innovation-related activities. We define a high level of innovation intensity when it is carried out systematically, involving all units in the firm and shaping the strategy strongly. At the other extreme, a low level of innovation would correspond to firms that use innovation occasionally and non-systematically, localized in some functional unit only.

Innovation is expected to result into higher survival rates, by means of producing a higher profitability, by increasing revenues or reducing costs, and maybe accessing new markets. In this sense, profits and sales growth may be already showing, at least partially, the effects of innovation. However, to gather more information on the effects of innovation, the share of new products is commonly used, which embodies in addition a success component, since these innovations are launched into the market and they are producing sales. New products are defined as the ones launched during the three previous years. This quantitative proxy of product innovation can be combined with the former qualitative measures, to produce a better, multidimensional, description of the innovation activity of the firm.

The third dimension is product and market characteristics. Under this dimension the length of the product life-cycle is a common variable to consider. According to the literature revised and the political recommendations, we also include in the questionnaire whether products are customer driven and the importance of design.

In the fourth and last dimension we consider a set of strategic characteristics, starting with the key success factors, defined as the main drivers of success perceived by the firms, the strategic strengths or capabilities that firms consider necessary in order to be competitive and survive in their markets. Respondents could openly answer this question first, and afterwards they responded quantitatively to the importance of a set of standard drivers of success: innovation, quality, productivity, marketing, finance, human resources, internationalization or strategic management. To gain a more in-depth knowledge on the rationale for innovation, we interviewed the firms about the reasons for innovation, with an open question and a quantitative question.

According to their key success factors, firms choose their strategic priority or direction, which is the dominant objective of their strategy, and their marketing and technological priorities, that we have named technological strategy. The technological strategy of each of the firms was an overall assessment of the researchers that allowed for several positions. The first type is the technological leader, when the firm is often a first-mover in launching new products or developing new technologies. The second type is the follower, when the firm prefers to wait for the movements of the leader and launch later offering some improvements. There is also the strategy of licensing, when firms acquire technology and know-how from leaders. Another possibility is to be a niche seeker, when the firm looks for opportunities that arise for a limited part of the market (niche), that leaders and followers are not attending properly. There are three other possibilities considered: that technological strategy is determined externally by customers or suppliers, that the firm uses different strategies for different products and that there is not a clear technological strategy.

The next section presents the results obtained from the analysis of these dimensions for each of the two groups of firms.

4.4. Results

The main descriptives of the 12 firms studied are presented in Table4.1 for each firm. Averages are not displayed since they are not informative in this case, due to the small size of the two samples and the important variance within each group for several variables. Table 4.1 shows that the two groups, HP (high-performing) SMEs and AP (average-performing) SMEs, are similar in composition as regards to NACE's codes and subsectors. The two main observable patterns of differences between the two groups are that HP SME are younger in all cases except one and that their turnover is more homogeneous and higher than most of the cases in the AP group. This latter feature may indicate two possible reasons, both of them positive: either high-performing firms have a higher productivity, since they sell more with a similar number of employees, or they may be selling higher value-added products.

Table 4.1: Descriptives for high-performing SMEs and average-performing SMEs in the T/C sector

	NACE* code	Subsector	Age (years)	Employees (number)	Turnover (millions €)	Distribution of sales (%)		
						Spain	EU	Non-EU
HP SME	17140	Fibre spinning	19	40	20,03	20	65	15
	17210	Cotton spinning	22	110	16,83	25	45	30
	17303	Finishing	33	154	12,02	100	0	0
	17400	Clothing	28	40	7,21	60	30	10
	17530	Fibre spinning	116	180	12	65	5	30
	17720	Clothing	14	40	6,61	30	63	7
AP SME	17150	Fibre spinning	33	190	25	20	75	5
	17210	Cotton spinning	156	106	6	30	70	0
	17301	Finishing	120	114	75	40	40	20
	17541	Fibre spinning	116	120	9	70	30	0
	17542	Finishing	20	35	6	10	45	45
	17720	Clothing	14	22	0,8	100	0	0

*NACE: Nomenclature Generale des Activités Economiques dans I´Union Européenne.

Another positive feature for HP firms is that they are able to obtain higher revenue with less age of experience. This fact indicates that HP firms have enjoyed on average greater rates of sales growth over time compared to AP firms, and not only during the three years that were used to select the sample. The advantage of HP firms in sales growth would be defined as higher success, and we contend that there must be some systematic behaviour or strategy that explains the differential success: maybe their R&D investment, their innovation commitment, their product development strategy, technological options, or partnering. The following analysis will explore these possibilities. Table 4.2 presents the comparative results for the two groups of firms regarding the four remaining dimensions under analysis, which will be analysed in turn.

Knowledge generation and acquisition

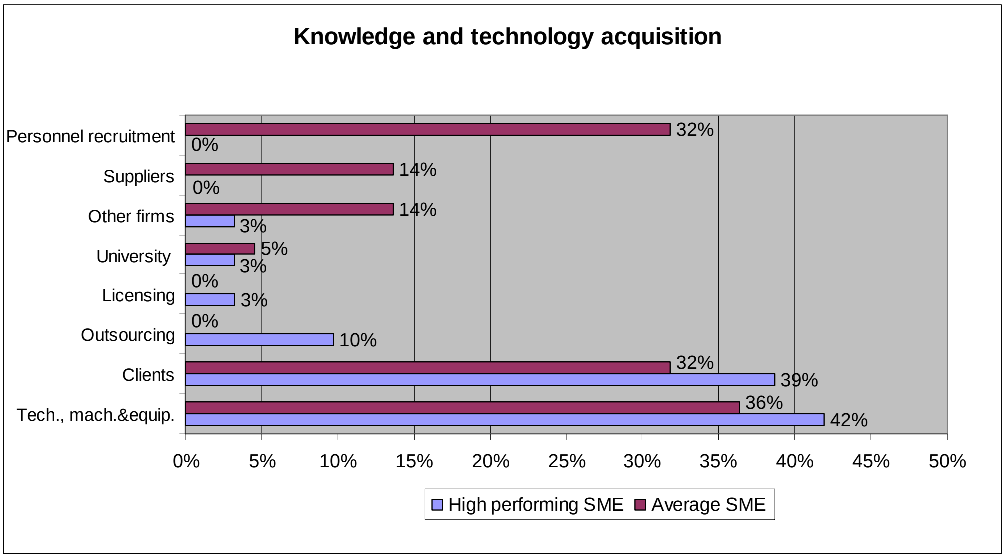
HP firms have lower R&D indicators in terms of personnel. Another feature is a lower level of education than the one characteristic to AP firms. This is a bit contrasting with the fact that HP firms obtained a higher volume of sales than AP firms, with a similar number but less qualified personnel. As regards to R&D expenditure, some AP firm reveal higher rates than HP firms. However it is interesting to highlight that all HP firms have an R&D budget, while only half of the AP textile companies do so. Contrary to what AP firms state, HP do not identify R&D cooperation or outsourcing as needed for their competitiveness: they do not rely on external cooperation for their success. But although AP firms state that cooperation is important, they maintain a low level of cooperation, including contracting with universities, equivalent to the one of HP firms. Both groups also share a similar low use of fiscal incentives.

R&D indicators are proxies of internal resources and capabilities, which may be complemented with external sources of knowledge and technology. Figure 4.1 represents the use of external sources of knowledge and technology acquisition. The two most ranked sources are technology and machinery acquisition, and clients, for both HP and AP SMEs. The differences come from the higher importance than HP firms give to these factors, and the fact that AP firms point to the recruitment of personnel as an outstanding source of knowledge acquisition, with the same importance than clients. Furthermore, suppliers and other firms have a considerable importance for AP firms, but not with HP firms.

Table 4.2: R&D, Innovation, Product and Strategic profiles for the two samples of SMEs

	High-performing SMEs	**Average- performing SMEs**
Knowledge generation and acquisition		
Expenditure	Average <2%	Varying High (>3%) or inexistent
Personnel	Less	More
R&D department	Seldom formalized	Seldom formalized
Knowledge and technology acquisition	Purchasing machinery, equipment and technology. Clients	Purchasing machinery, equipment and technology. Clients Personnel recruitment
Importance of R&D cooperation or outsourcing	No	Yes
R&D contracting level	Low	Low
Innovation activity		
Innovation intensity	High	Low
Product vs. process innovation	Product	Process
Main source of ideas for innovation	Clients	Other firms
Share of new products	Higher	Lower
Product and market characteristics		
Life cycle	Longer	Shorter
Customer-driven products	More	Less
Importance of design	Maximum	Varying but average
Strategic characteristics		
Key success factors	Innovation Quality Productivity	Quality Innovation Productivity
Reasons for innovation	Increase market share Enter new markets	Enter new markets Increase market share
Strategic priority	Innovation	Technology and quality
Technological strategy	Niche and demand pull	Leader

Figure 4.1: Knowledge and technology acquisition for HP and AP SMEs



Innovation activity

While R&D indicators do not explain the better performance of HP firms, innovation activity reveals a positive differential trait. As summarized in Table 4.2, the indicators of innovation activity reveal that HP firms have a higher, more systematic, innovation process with more product innovations than process, and a higher proximity to customers as a source of knowledge and ideas for innovation. The result is that HP firms have a higher share of new products, defined as the ones launched within the last three years.

Product and market characteristics

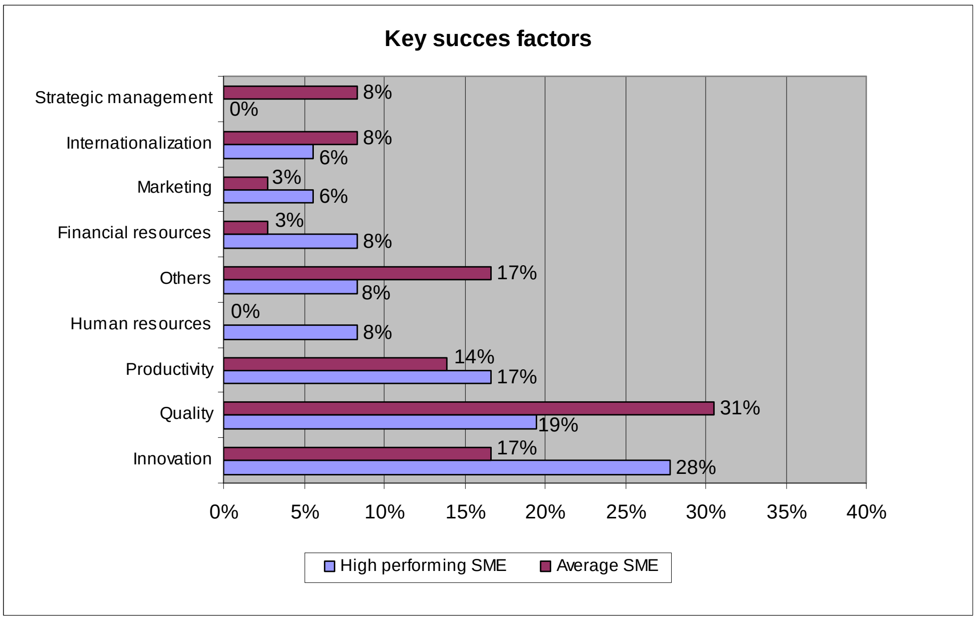
As regards to product and market characteristics, product life-cycle is longer for HP firms, their products are more customer-driven and design becomes of maximum importance.

Strategic characteristics

To achieve success in their markets, firms pursue their perceived success factors. We illustrate the results to this question in Figure 4.2. Although the two groups share the two most important key success factors, they differ in importance considerably.

While innovation is the most important key success factor for HP firms, AP firms indicate that quality is the most important. We interpret this finding as we contended before; successful SMEs have a more proactive attitude, pursuing innovation more over quality. The third key success factor is productivity, which is equivalent for both groups. It is also worth noting that human resources and finance are appreciably more important for successful firms, while strategic management is only pointed by average firms.

Figure 4.2: Key success factors for HP SMEs and AP SMEs in the textile sector



Consistently, the HP firms interviewed responded that their strategic priority was innovation, whilst technology and quality was the strategic priority of AP firms. Their technological strategy is also different. HP firms tend to have a niche strategy and a demand pull orientation, while AP firms aim to achieve leadership in their markets, although they do not succeed in achieving it.

Firms in both groups share the belief that innovation will help them to increase market share in their markets and entering new markets. However there is a slight difference between the two groups: HP firms rank 'increase market share' higher, while AP firms rank 'enter new markets' as higher. We relate this results to the possibly different markets that the two groups face: younger markets for HP firms, where there are still possibilities for growth, and more mature markets for AP firms.

4.5. Conclusions

HP firms are more homogeneous than the AP sample of firms, in size, revenue and in strategy. HP firms do not excel in R&D indicators (investment or personnel), they have lower internal resources dedicated to R&D but their position is more systematic than the one in the AP sample. They do not consider external R&D collaboration important, neither establish formal collaborations with universities. They rarely use R&D support mechanisms or incentives. The main differential external knowledge acquired by HP firms comes from customers, which inspire and suggest innovations. Differently, AP firms tend to exercise pressure on suppliers to innovate or they acquire external knowledge from recruiting new personnel. Firms belonging to the same subsector did not show any observable common pattern and distinguishable from the one of firms in other subsectors.

HP firms outstand in innovation as strategic priority, as their commitment, that translates into a niche strategy, of proximity to the customer, which is the main source of ideas. The innovation focus translates into more product than process innovation and more share of new products. They aim to increase market share in current markets, which we suppose to be less mature than the ones of AP firms.

In our study, technological leadership strategy is not associated with success, while a niche strategy is. We think that the rationale behind this result is that success for SMEs is more likely to happen when they pursue a focus strategy than an all market strategy, in terms of the generic strategies (Porter, 1980). The limited dimension of those firms (SMEs) fits better a niche or focus strategy, which goes along with a small market. Following other works on strategic types, the niche strategy resembles the defender strategic type (Miles and Snow, 1978) which was also found to be the most common strategic type in a previous study for the textile sector in a province of Spain (Llach et al., 2006).

We have explored four possible dimensions to explain the differential traits of successful versus average SMEs firms in the textile and clothing sector. The most different dimension for successful firms was the innovation dimension. The foundation of this difference is found in a different perception of competition, in terms of the key success factors. This difference translates into a different strategic priority and technological strategy, which in turn implies different innovation activities and results. Eventually, the market is judging that one of the two visions is better than the other.

Chapter 5. The use and impact of technology in factory environments: Evidence from a survey of manufacturing industry in Spain

Resum

L'objectiu d'aquest treball és estudiar el procés d'implantació de tecnologies en planta i de la informació a l'empresa tenint en compte el grau d'ús d'aquestes tecnologies. Apart, s'analitza si la mera implantació causa un efecte directe en els resultats de l'empresa o bé si és necessari un alt grau d'implantació. Les dades empíriques utilitzades en aquest treball provenen de la informació recollida a 151 empreses mitjançant l'Enquesta Europea de Innovació en Producció - edició 2006.

Els resultats mostren com la tecnologia més implantada és el Disseny Assistit per Ordinador (CAD) seguit per els ERP i els robots industrial. Quan s'analitza a partir del grau d'implantació, la tecnologia més altament implantada continua essent el CAD, ERP i robots industrial. Mitjançant una regressió múltiple es mostra com existeix una correlació entre el grau d'ús i resultats. La relació entre adopció i resultats és menys intensa. Aquest resultats tenen implicació en el desenvolupament de futures polítiques i plans estratègics per fomentar la completa implantació de les tecnologies analitzades de cares a millorar els resultats de les empreses.

Abstract

The aim of this paper is to examine information related to the implementation of shop floor technologies and information technologies. This will be complemented with data relating to different levels of usage of the technologies. In addition, we test whether implementation alone is able to improve company performance or whether a high level of usage is also important. The empirical evidence comes from a sample of 151 Spanish manufacturing companies surveyed according to the European Manufacturing Survey's methods in 2006.

Our results show that the most widely adopted technology is computer-aided design (CAD), followed by enterprise resource planning (ERP) and industrial robots. When the focus is on the level of use, the most highly used technologies turn out to be very similar—CAD–computer-aided manufacturing, ERP, and industrial robots—. Multiple regression analysis shows a positive correlation between the variable "level of usage" and performance. The relationship between adoption and results is less strong. These results have some implications and the paper ends with an explanation of how these findings should be used by firms in the development of future policies or strategic plans.

5.1. Introduction

The use of different manufacturing technologies in factories is an important aspect in the evaluation of the impact of innovations in enterprises. One widely adopted model is to study the impact of Advanced Manufacturing Technologies (AMT) on performance. Nowadays, competition has intensified and shifted from the national to the global arena and product life cycles have shrunk, yet there is a growing requirement to satisfy customers' specific and individual needs (Jin-Hai et al., 2009).

Some recent studies contemplate AMT and their influence on performance (Koc and Bozdag, 2009) or AMT from an adoption perspective (Thakur and Jain, 2008) in a delimited geographic area. Our objective is to combine the previous two dimensions presenting adoption rates and depths in relation to performance for Spanish manufacturing companies.

The way in which manufacturing systems have responded to customer requirements can be analyzed from different perspectives. The focus on manufacturing strategy has changed over time. Modern manufacturing practices have been of interest to academics, policy-makers and practitioners since the introduction of "Taylorism" and traditional studies on work organization principles. Such studies have more recently been replaced by a range of new practices originally associated with the Japanese manufacturers. First, there was a focus on mass production, then on quality, afterwards on service, and most recently there has been a move towards agility and flexibility (Theodorou and Florou, 2008) or extended enterprises (Browne et al., 1995; Folan and Browne, 2005).

These trends have been accompanied by different approaches such as Material Requirement Planning (MRP) promoted by the Association for Operations Management (APICS), Computer Integrated Manufacturing (CIM), World Class Competition, Total

Quality Management, Lean Manufacturing, Agile Manufacturing, and so on. Management has responded to these competitive environmental pressures by developing new approaches, concepts and methods. The result is the increasingly rapid evolution of business systems and the creation of new manufacturing and management philosophies needs (Jin-Hai et al., 2009). As Sharp et al. (1999) stated, "There are many manufacturing panaceas".

However, there is a common element in all of these approaches, namely the impact of Information Technology (IT) and the opportunity to integrate the functional areas of the enterprise. The term IT is viewed in a broad sense, following Cooper and Zmud (1990), and as such it refers to any artefact whose underlying technological base comprises computer or communications hardware and software.

The principal element of the integration was to have a common or an interconnected database to facilitate automatic data transfer among various units and user groups. It has been argued that this is essential to support the concept of integrated manufacturing. A variety of potential benefits could be produced, but they are very difficult to quantify with simple economic tools. Integration provides a competitive advantage by linking new and existing hardware, software and middleware of the functional units, together with database management systems, data communications systems and other IT systems to form a coordinated and efficiently managed process (Nagalingam et al., 2009).

Manufacturing philosophies follow fashions, and a particular philosophy may be in or out depending on managerial focus or management commitment, but the main idea that remains constant is that the firm must be willing to satisfy specific and individual customer needs all of the time. This has become a way of life, not to say a necessity for survival, in a manufacturing environment that has become increasingly difficult (Zhang, Z. and Sharifi, 2000).

In order to give the present study a precise focus when studying the role of AMT on enterprise performance, we choose not to consider global philosophies such as Total Quality Management (TQM) or Lean Manufacturing. Instead, we focus attention on specific elements, found in AMT firms.

The term AMT is used in this research as an umbrella term to describe a variety of technologies which primarily utilize computers to control, track, or monitor manufacturing activities, either directly or indirectly. We could include technologies such as computer numerical control (CNC) machine tools, computer aided design (CAD), and electronic data interchange (EDI) since all involve the use of computers to control tools and machines, store product information and control the manufacturing process (Boyer et al., 1997).

The benefits promised by AMT, and others of the previously mentioned panaceas, are lower production costs, high product quality, improved product control, better responsiveness, reduced inventory and increased flexibility. Nevertheless, along with the direct and tangible benefits, intangible and indirect benefits also arise from effective integration. Therefore, a grounded investment in AMT can be fully justified. In the last decade, even though there are success stories in AMT implementation, there were more failures than successes in AMT implementation (Boyer et al., 1997). This tendency has changed and the adoption becomes a requirement instead of a competitive advantage.

Our first aim is to report information related to the process of implementation, namely the proportion of Spanish manufacturing firms that implemented such techniques at a particular time, together with information about the level of usage of those elements. In addition, we test whether implementation alone or a critical level of usage has a more significant impact on a company's performance.

The empirical evidence comes from the European Manufacturing Survey (EMS), an international survey combining innovation, production, organizational and technological measures. The complex methodology behind the survey is a necessity nowadays, as there is a need to capture evidence that covers all aspects of a manufacturing process, in a standardized and systematized way. As Bolden et al. have noted, "There is currently a need for comprehensive and systematic surveys covering an adequate sample and range of manufacturing practices, industrial sectors and company sizes" (Bolden et al., 1997).

The paper is structured as in the following way. In Section 5.2 we briefly review the literature on manufacturing, and also identify the research related to our selected AMT, (CAD, CAM, ERP, etc.) In Section 5.3 we develop the hypotheses, and in Section 5.4 describe the methodology and the sample used to provide empirical evidence for the present study. In Section 5.5 we present the results, namely a description of the implementation of procedures, and the different levels of use of those innovations, as well as the results of the tests conducted to contrast identify the important determinants of company performance. Finally, Section 5.6 presents the conclusions and highlights the main implications of our study.

5.2. Literature review

In this article we focus on the elements that are characteristic of CIM, as a set of AMT. CIM may be considered a classic approach among the manufacturing panaceas that have been mentioned above. In Bolden et al.'s (1997) taxonomy of modern manufacturing practices, CIM refers "to the potential for a truly integrated manufacturing effort from product conceptualization and design right through to assembly and after sales service using a common system and a common database" (Storey, 1994). CIM is included in the taxonomy as one of the approaches that focuses on improved technology. This area is then further subdivided into four main categories according to their primary domain of application. First, design and production includes CAD, CAM, CNC, CIM, CAE, automation using robots and automated guided vehicles. Second, inventory and stock systems refer to automated storage and EDI. Third, the work organization category embraces FMS, group technology and manufacturing resource planning (MRP), among others. Fourth, the wider organization of manufacturing deals with technology for the entire company, computer based management tools and benchmarking for technology, all IT intensive items.

Therefore, CIM is a generic term that incorporates a variety of AMT: computer aided design (CAD), computer aided manufacturing (CAM) computer aided process planning (CAPP), computer aided quality (CAQ) and planning and control of production systems (PCPS). However, we suggest that the implications of CIM for the organization are too far reaching for it to be regarded as simply an aid to production (Nichols and Jones, 1994). Many of these AMT contribute in some sense to the enhancement of results in manufacturing firms. It is very difficult to isolate the effect of a specific technology. Despite these difficulties, efforts should be made to measure the benefits arising from any particular technology.

The implementation of AMT in a firm can be seen at different levels. The lowest level is the shop floor or manufacturing operations, where the main idea is linking the "islands of automation". The highest level is composed of two dimensions: Information Systems Integration, where information is shared across functional boundaries; and the strategic level or "Supply Chain Management", where integration extends up to customers and down to suppliers. For the purpose of the present study we have chosen to analyze these two levels of AMT.

The first level is represented by the use of shop floor manufacturing technologies (SFT). These include: (1) Computer aided design (CAD); (2) Computer controlled machinery or equipment (CAM); (3) Integration of design and computer controlled machinery (CAD-CAM); (4) Industrial robots and automated handling systems (for tools or parts) and (5) Computer controlled warehouses/material handling systems.

The second level is represented by the use of ERP system to manage the production system and the use of Supply Chain Management (SCM) systems. It may be difficult to distinguish these last two approaches, because many ERP systems have evolved to deliver SCM system integrating functions through electronic commerce or EDI. Therefore we propose a merged category, namely Information Infrastructure Manufacturing Technologies (IIT). It includes: (1) Enterprise Resource Planning software (ERP) and (2) Exchange of production schedule data with other companies (Supply Chain Management).

The SFT are dealt with at some depth in the literature and their impact on business performance has been repeatedly demonstrated. Theodorou and Florou (2008) present the influence of CAD/CAM on return on invested capital by means of a cluster analysis. It was found that in all of the strategic clusters, performance was increased by the adoption of advanced information technology.

One driver of integration of technologies in manufacturing has been Enterprise Resource Planning (ERP) systems, a popular information technology (IT) in the changing business environment of the 1990s (Chung and Snyder, 2000). One of the major characteristics of ERP has been the integration of different functional areas of an enterprise. It allows production systems to develop the real CIM potential which lies in creating a network of people and activities to accelerate decision making, minimize waste, and speed up response to customers while producing a high quality product.

In this sense, ERP has contributed to the explosion and extension of CIM as a wider concept. The evolution of manufacturing systems has led to information integration. ERP combines both business processes in the organization and total organizational IT into one integrated solution. It has been suggested that ERP is an extension of MRPII (formerly MRP) with enhanced and added functionality. The need for software specifically designed for manufacturing operations led to the development of ERP packaged software (Chung and Snyder, 2000).

The latest technology is the Supply Chain Management approach. Although this is prominent in the literature, it is not as widespread in its application as was expected (Sabrià, 2004). According to Christopher and Towill (2000) it is becoming increasingly apparent that competitive advantage derives from the combined capabilities of the network of linked organisations and the name of this phenomenon is “the supply chain”. This is a fundamental shift from the traditional business model based upon a single firm.

The requirements of manufacturing have changed tremendously and isolated integration now represents an inadequate business solution. There is a need for a move towards an enterprise-wide system which should enable various functions within an organization to obtain the right information in real-time, thereby enabling the organization to improve its response rate (Yusuf and Little, 1998).

The literature demonstrates that one of the major business objectives in manufacturing has been the elimination of barriers between different functions in a firm (Chung and Snyder, 2000) and one way to achieve this objective is for the firm to integrate tasks and technologies in its manufacturing processes. Accordingly may be interesting to inquire whether technologies which we expect to find in the shop floor environment contribute to enhanced performance in terms of results. With the aid of Information Technologies (IT) such as ERP or SCM, the factory is re-emerging as the focal point of corporate strategy, and CIM is viewed as the key element in global competitiveness (Attaran, 1997). Moreover, there are some authors who argue for new concepts or new strategies that go even further, towards the extended enterprise paradigm (Moller, 2005; Christopher, 2000).

Finally, the effective introduction of all AMT is dependent on the organizational context, but wider issues must also be taken into account. Frequently, top executives view CIM just as technology, a master computer controlling many robots and automated machines. They are wrong; if CIM were just technology, there would not have been as many companies having difficulties in implementing it. CIM is a conceptual approach; it is a way of using technology and techniques to integrate a business.

CIM is the management of technology rather than a technology itself. It is the integration of people and functions utilizing the computer and communication networks to transform automation into interconnected manufacturing systems (Nichols and Jones, 1994). In this sense, there is a group of organizational and strategy related factors which can support the smooth introduction of CIM.

If the challenge of CIM in the past was to realise integration within the factory, the challenge to manufacturing in the future is to facilitate inter-enterprise networking across the value chain (Folan and Browne 2005). But it has become apparent that nowadays, results do not live up to managers' expectations: 85% of companies consider ERP as an investment for more than 5 years, 70% expect no more than 25% by way of return on investment and 50% did not even try to estimate the ROI (Botta-Genoulaz and Millet, 2005). The technical and managerial challenges of implementing ERP systems are widely researched and analyzed in literature, but the problem of assessing the benefits of ERP systems is less well studied and understood, despite the observation that the difficulties experienced in measuring the business value of ERP systems are not atypical of most IT projects. The question of how to measure the benefits of ERP in use has been raised but not fully analyzed (Chand et al., 2005). Therefore, we believe that it is timely now, some time after these technologies have been implemented, that results and performance related measures should be evaluated.

5.3. Hypothesis formulation: Implementation versus level of usage

The literature abounds with studies reflecting the implementation of technologies (Christopher and Towill, 2000). A typical research question could be, "*Has your enterprise implemented X solution/technology?*" giving the respondents the option of answering with yes or no. Against this background we propose H1:

H1: the implementation of more CIM-related technologies has a positive effect on performance.

To complement the question of mere implementation, we differentiate between different levels of usage. Moreover, our questionnaire (see the Appendix 5.A) collected data on the different extent of use at the previously defined levels (shop floor and/or information infrastructure). Companies were able to describe the extent of actual use of the technologies in comparison with the level that they thought represented the potential use for the company; they categorised the level of use as "low" (recently introduced, not achieving full potential), "medium" (partial usage) and "high" (usage close to full potential). According to these categories and as a result of this approach we would expect H2 to be confirmed:

H2: A high level of implementation of CIM-related technologies has a positive effect on performance.

5.4. Methodology

5.4.1. Sample

Empirical evidence for the present study came from the Spanish sub-sample of the European Manufacturing Survey (EMS) which is briefly described here. The EMS, coordinated by the Fraunhofer Institute for Systems and Innovation Research – ISI – in Karlrushe, Germany, collected detailed information on manufacturing firms. The topics covered by the survey can be summarized under 7 main headings, namely competitiveness, production technologies, organizational concepts, product related services, cooperation, off-shoring, firm and sector characteristics (Lay and Maloca, 2004).

The EMS tries to contribute to the standardization of use of information on organizational and technological topics. In recent years, different surveys have been launched with the aim of measuring the use of new technological and organizational approaches. The great disparity of methodologies used previously resulted in a low degree of comparability among the data collected. EMS is not intended to be a "new" or "better" monitoring system. Rather it proposes a complex methodology as a first step towards a common method for collecting technological and organizational information. However, these are general features of the EMS "philosophy". A set of core questions is common for all countries, while a set of country-specific questions refer to each country's specific circumstances and/or research interests.

In the last (2006) edition EMS has been carried out in 12 countries (Austria, Croatia, France, Germany, Greece, Netherlands, Slovenia, Spain, Switzerland, Turkey, United Kingdom and Italy), resulting in approximately 3,500 responses.

For the purpose of the present paper, the sample consisted of the Spanish firms and was further restricted to manufacturing enterprises (NACE Code 15-37) and to companies having at least 20 employees. The Spanish National Statistic Institute facilitated the identification of all manufacturing establishments having these characteristics, as well as the distribution of the questionnaire. Approximately 10% of the population received the EMS questionnaire. The questionnaire was sent out by post to the selected firms in two rounds. The first round was sent out in April 2006, with a follow up in June 2006. Besides the common core questions included in the questionnaires of the twelve countries, the Spanish questionnaire contained three additional questions thematically related to safety culture, family business and team work organization.

Our final dataset consists of 151 entries. The results obtained have a confidence level of 83%, taking into account a margin of error of 5% (p=q=0.5).

Table 5.1 contains some descriptive statistics of the sample. The results are presented according to the OECD's classification of manufacturing industries classified by their technological intensity. Since our high technology industry group involves only four companies this group was merged with the medium-high technology industry group. Some features regarding the sample refer to the bigger size companies in the low-technology industries according to the average number of employees, highest turnover in the medium-high and high-tech sector.

Table 5.1: Summary of descriptive features of the sample by technological intensity

	Low-technology industries	**Medium-low technology industries**	**Medium-high & high technology industries**
NACE	36-37, 20-22, 15-16, 17-19	23, 25, 26, 351, 27, 28	31, 34, 24 excl. 2423, 352 + 359, 29 and 353, 2423, 30, 32, 33
N	49	49	53 (49+4)
Sample			
Employees (2006)	268	150	167
Turnover (2006)	59,78 M€	29,20 M€	191,49 M€
Machinery and equipment investments (2006)	19,52 M€	1,27 M€	1,89 M€
R&D expenditure as % of turnover	1,91	3,04	2,72
% Export (sales of product abroad)	27,11	33,67	39,53
% Import (inputs from abroad)	16	22	31
Year of foundation	1966	1955	1959
Degree of capacity utilization	81,10	80	78,13
Technologies			
CAD (n)	34	33	42
CAM (n)	17	25	27
CAD-CAM (n)	16	13	21
ERP (n)	27	30	28
Industrial robots (n)	23	27	28
Supply Chain Management (n)	9	5	8
Computer Controlled warehouse (n)	6	4	9

Traditional industrial sectors in the low-tech group have a surprisingly high investment in machinery and equipment. Interestingly, the innovation input proxied by the R&D budget does not follow a linear trend along the technology groups, medium-tech industries in our sample having the highest investment in R&D, approximately 3% of their turnover. Regarding technologies distribution along the considered industrial sectors, since the companies distribute almost evenly, minimal differences are worth noting. The general trend is that the medium-high and high tech sector is more abundant in technologies adoption except for two particular cases. ERP adoption is slightly higher in medium-tech industries and SCM is minimally higher in low-tech industries. Our results show, up to some degree, no considerable gaps among the sectors in terms of technologies' adoption.

5.4.2. Variables

In order to test both hypotheses we used the information collected in the survey. We computed the variable SUMTEC to analyze the effect on results of the mere implementation of different technologies. We also computed the variable SUMHIGH to analyze the effect on results when the different technologies were used at a level close to their full potential (high level of usage) throughout the firm.

SUMTEC – sum of technologies used; it takes values from 0 to N (according number of technologies in the model). This means that SUMTEC represents the number of chosen technologies that the firm had implemented.

SUMHIGH – sum of technologies having a high level of usage; it takes values from 0 to N (according number of technologies in the model). This means that SUMHIGH represents the number of chosen technologies that had a high level of implementation in the firm.

The results or performance variable used for conducting the analysis was Return on Sales – ROS, a ratio widely used to evaluate a company's operational efficiency. ROS is also known as a firm's "operating profit margin". It is calculated by net income (before interest and tax) divided by sales. This measure is helpful to management, providing an insight into how much profit is being produced for each unit of sales income. As with many ratios, it is best to compare a company's ROS over time to look for trends, and compare it to other companies in the same industry. An increasing ROS indicates that the company is growing more efficient, while a decreasing ROS could signal looming financial disaster.

The questionnaire collected information on the value of ROS, before interest and tax in 2005, (less than 2%, up to 5%, up to 10% and more than 10%) and it reflected the general opinion of the respondent, being a perception rather a result of a computation. Other variables – sector by technological intensity and turnover – were used as control variables in the multiple regression analysis.

5.5. Results

5.5.1. Descriptive analysis

Figure 5.1 shows the classification of the most widely implemented technologies. The most common technology was CAD (73%) followed by ERP (59%) and industrial robots (52%). From the seven technologies analyzed in this study these were the only three technologies with a percentage over the second quartile. The two least widely implemented technologies in our sample were Supply Chain Management (15%) and the Computer Controlled Warehouse (13%).

Figure 5.1: The implementation of shop floor and information infrastructure technologies

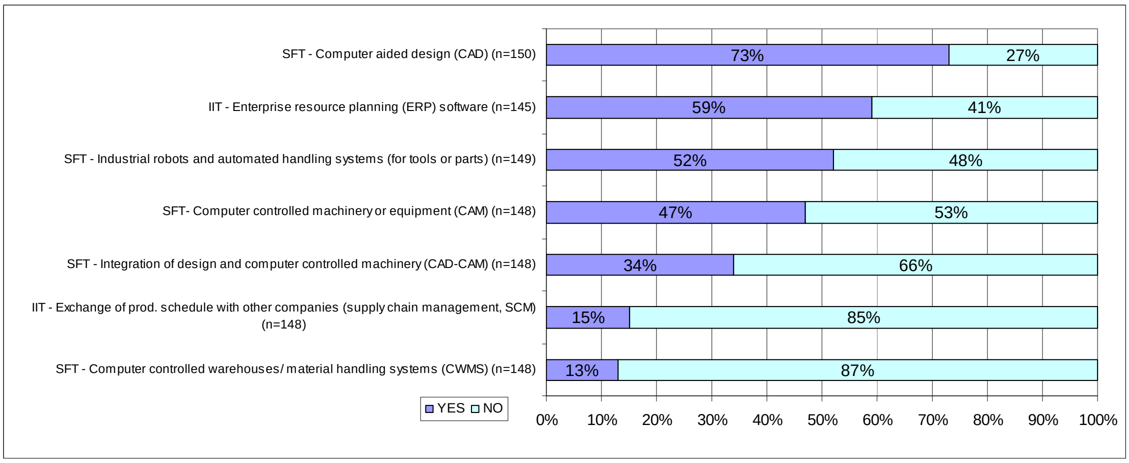
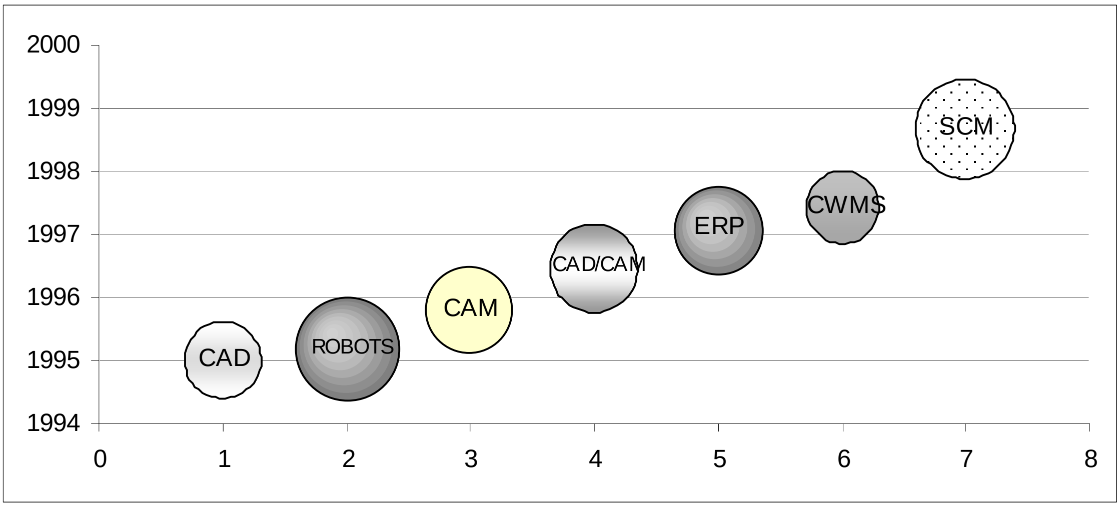


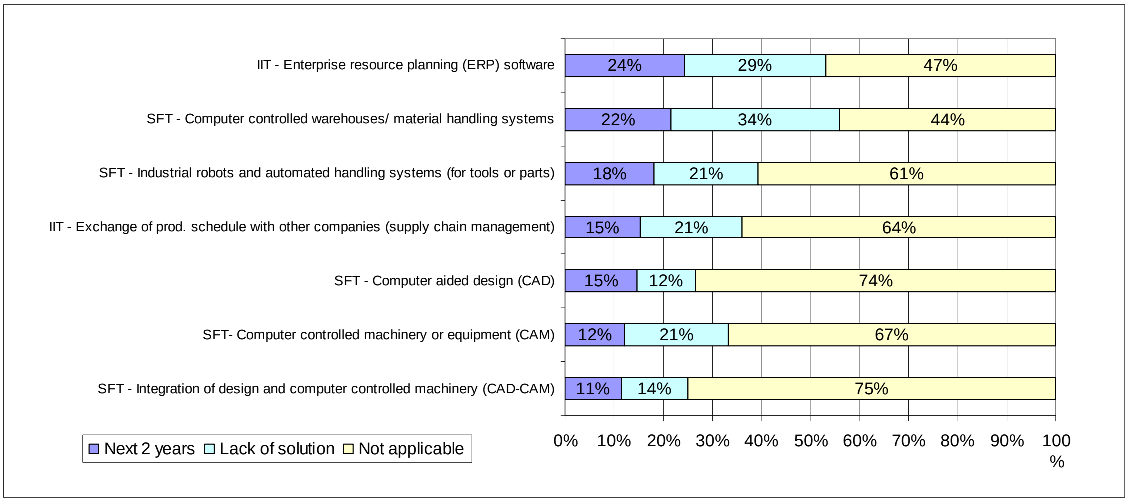
Figure 5.2 shows the evolution of implementation over time. Average values of the year of implementation show CAD, industrial robots and CAM being introduced earlier. In contrast with this, the most recently introduced technologies were ERP, CWMS and SCM.

Figure 5.2: Average year of implementation of shop floor and information infrastructure technologies



Concerning future implementation, in the following two years, companies reported a higher likelihood of implementing ERP (24%). Interestingly, among the technologies that were not considered to be a solution to the company's problems, or as being less applicable in the plant, Computer Controlled Warehouses/material handling systems (34%) were the most frequently identified. Among the technologies that were identified as not being applicable in most cases companies mentioned the integration of design and computer controlled machinery most frequently.

Figure 5.3: Non- implementers' prevision for shop floor and information infrastructure technologies

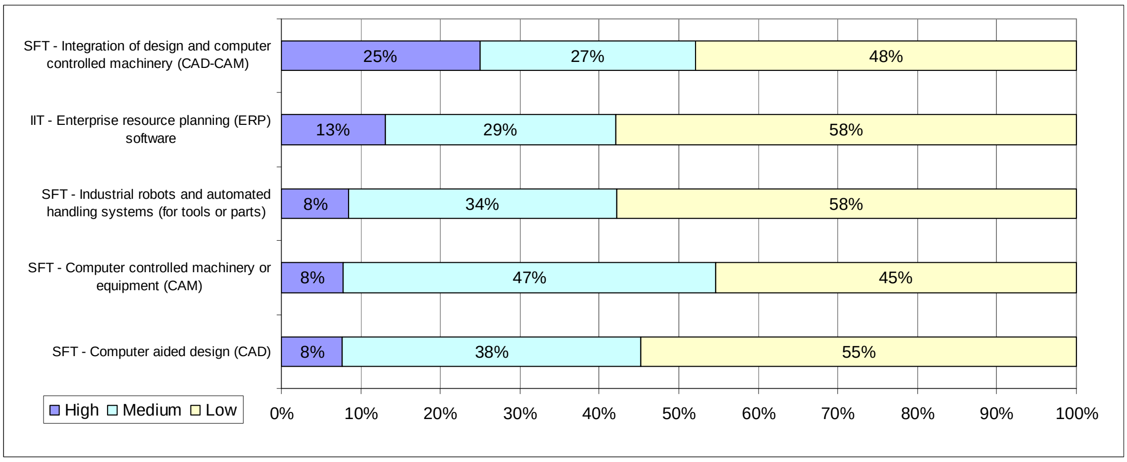


These results suggest that, taking into account those technologies that could already be found in companies and those that firms identify as most likely to be implemented in the short term, ERP will soon become the most frequently adopted technology in the business sector. On the other hand, technologies like Computer Controlled Warehouse, which are seen to be useful/applicable in only a few concrete sectors, will continue with low implementation within the whole set of firms.

When the focus is on the level of usage (low, medium, high) the results show that the most commonly implemented technology (CAD) is not the one having the highest level of usage. One quarter of the companies in the sample reported CAD-CAM to be the technology with highest level of usage, followed by ERP (13%).

There are two reasons that only 5 out of the initially 7 selected technologies are shown in Figure 5.4. Two technologies (CWMS and SCM) are omitted in this second part of the analysis because of the low level of usage (see Figure 5.1) and because of their relatively recent adoption (see Figure 5.2). Both of these factors might have a bias effect when evaluating their impact on results.

Figure 5.4: The implementation degree of shop floor and information infrastructure technologies



5.5.2. Implementation versus level of usage

The data set was analyzed using an ordinal logistic regression model. This technique is appropriate since the dependent variable ROS and its multiple classes can be ranked. On the one hand, ROS takes values from 0-2%, 2-5%, 5-10% and more than 10%, the lowest being the reference category.

On the other hand, the technology variables intuited as having explanatory power were considered: first, the number of technologies implemented (SUMTEC), and second the number of highly implemented technologies (SUMHIGH). To isolate the relationships studied two variables were incorporated as control variables. The first refers to industrial sector taking values of low, medium, high. The second variable is turnover.

Furthermore, and in order to carry out a more precise analysis of the relationships analyzed three different regression models were computed: one, incorporating the control variables, as independent variables, a second model considering the technological variable and third taking into account all the above described dimensions.

The results are presented in Table 5.2 and 5.3. Each of the proposed hypotheses was tested in turn.

H1: The implementation of more CIM-related technologies has a positive effect on performance.

Table 5.2 shows the results of the first ordinal regression model allowing us to study Hypothesis 1. Model 1 which only includes the control variables as predictors of performance reveals that belonging to the medium technology intensity sector increases the likelihood of having a ROS superior to 5%, while belonging to the high technology intensity industry raises the probability of having a ROS superior to 10%.

Model 2, which includes the technology variable in terms of number of technologies implemented, reveals that this measure is not a good predictor of higher performance. However, when this variable is introduced together with the control variables in Model 3, the difference is minimal compared to model 1. This means that SUMTEC is not able to explain anything different of what the control variables do. Therefore we conclude that a higher number of technologies implemented are not a good predictor of higher performance. For this reason, we reject H1.

Table 5.2: Relationship between company features -sector, turnover, number of implemented technologies- and performance: ordinal logistic regression

	Model 1			Model 2			Model 3		
ROS	2-5%	5-10%	>10%	2-5%	5-10%	>10%	2-5%	5-10%	>10%
Constant	1,10	0,31**	0,13**	1,23	1,65	0,68	1,13	0,51	0,17
High intensity	1,66	3,04	8,08**				1,91	2,77**	7,25**
Med intensity	1,25	8,40***	9,90**				1,25	7,52	8,87**
Turnover	1,01	1,01	1,01				1,00	1,01	1,01
SUMTEC				1,06	0,92	1,03	1,03	0,87	0,96
Likelihood			20,662**			0,667			20,518*
R^2 (Cox and Snell)			0,207			0,008			0,212
R^2 (Nagelkerke)			0,222			0,008			0,227
R^2 (McFadden)			0,086			0,003			0,088

****p<0.01; **p<0.05; *p<0.1*

H2: The high implementation of CIM-related technologies has a positive effect on performance.

The information gathered in Table 5.3 allows us to analyze Hypothesis 2. Again three models are considered. Model 1 is identical to the one described previously since all the control variables and the dependent variables remain unchanged. Model 2 shows that having more highly implemented technologies is a good predictor of a better performance. More specifically the model shows that having more highly implemented technologies differentiates companies having a ROS superior to 10%. Model 3, joining control variables and the technology variable, reveals that the coefficient of the technology variable increases when the control variables are included in the regression. Since the significance level remains unchanged while all coefficients included in the model increase, we conclude that the higher the level of implementation, the higher the return on sales. Furthermore, the goodness of fit of the model shows a significance level of 90%. As a result of these findings, we accept H2.

Table 5.3: Relationship between company features -sector, turnover, number of highly implemented technologies- and performance: ordinal logistic regression

	Model 1			**Model 2**			**Model 3**		
ROS	2-5%	5-10%	>10%	2-5%	5-10%	>10%	2-5%	5-10%	>10%
Constant	1,10	0,31**	0,13**	1,50	0,95	0,33**	1,08	0,22**	0,05***
High intensity	1,66	3,04	8,08**				1,69	3,04	7,82**
Med intensity	1,25	8,40***	9,90**				1,25	8,87***	11,40**
Turnover	1,01	1,01	1,01				1,01	1,01	1,01
SUMHIGH				1,00	1,26	1,68**	1,01	1,34	1,73**
Likelihood			20,662**			6,403*			27,094***
R^2 (Cox and Snell)			0,207			0,069			0,262
R^2 (Nagelkerke)			0,222			0,074			0,281
R^2 (McFadden)			0,086			0,027			0,113

****p<0.01; **p<0.05; *p<0.1*

In summary, these results suggest that in order to improve performance mere implementation of a technology is not enough. Rather, what counts is the level of usage (high level) in producing an influence on performance.

5.6. Conclusions

Before advancing the conclusions arised from this contribution, we want to highlight that some literature reveals there are many factors to promote and incentive the AMT adoption. Some of them are the incremental sequence in AMT adoption from stand-alone to intermediate and then to integrated technologies (Spanos and Voudouris, 2009) who is the generator of the idea of AMT adoption (Hofmann and Orr, 2005).

For the first time in Spain, a survey has collected detailed information about the use of different technologies and patterns of organization used in manufacturing environments.

Together with ten other European countries, the European Manufacturing Survey (Spanish Edition, 2006) has extended its research to include features of the use of a set of technologies. The features analyzed have been the level of usage, the potential use and the first year of use of the technology. In the case of any technology that was not being used the survey asked for the main reason that would account for this fact, planned use over the course of the next two years, and whether the absence of a plan to implement the technology was due to fact that it did not offer a technological solution or whether it was simply not applicable in a specific plant.

This wide range of information has allowed the authors to carry out an in-depth analysis of the sample. Moreover, the existence of data on these issues from other ten European countries opens up the possibility of comparative research in the future which has not been included in this paper.

In reference to the sample, the most widely implemented technology was CAD followed by ERP and industrial robots. On the other hand, if the focus is on the level of usage, the most commonly implemented technologies were CAD-CAM, ERP and industrial robots. Looking to the future, the technologies which featured most commonly in future plans for implementation over the course of the next two years were ERP, computer controlled warehouse and industrial robots.

These results suggest that, in short term, the most widely used and rapidly increasing application of technology in Spain will be an Information Infrastructure Manufacturing Technology, ERP. One reason for this could be the evolution of strategy in the firms, due to the highly competitive environment of the market, and that companies are investing more in “strategic” technologies than “hardware” technologies.

The importance of a high level of usage, in contrast with mere implementation, is demonstrated through the model presented in this paper. While a model with one independent variable – that is the sum of the technologies implemented – is not significant, the same model with a different variable – that is the sum of technologies with a high level of usage – is significant. Furthermore, the goodness-of-fit of the model doubled. For this reason, we can conclude that until a technology is completely implemented, meaning that it is used effectively in the company, it will not affect the performance of the firm. In the case of the present study, the performance of the firm was measured by return on sales.

In conclusion, the wide range of detailed, descriptive information about the use of technologies in manufacturing environments and the opportunity to know how the situation will evolve over coming years makes it possible to contribute to the drawing up of specific policies to help Spanish firms to become more competitive within the global market. Policies adopted to facilitate and extend the use of technologies in firms and policies that promote the acquisition of "strategic" technologies could be examples of future directions that are supported by the present research.

Chapter 6. Relationship between quality management systems and organisational innovations

Resum

L'objectiu d'aquest treball és analitzar si existeix correlació entre la implantació sistemes de gestió de qualitat i l'ús d'innovacions organitzatives en empreses manufactureres.

Mitjançant la classificació sobre innovacions organitzatives proposada per Armbruster et al. (2008) i els nivells jeràrquics de la gestió de la qualitat proposats per Dale (2003) qualitat, el treball planteja una sèrie d'hipòtesis sobre la relació entre l'ús d'innovacions organitzatives i el nivell de qualitat dins una mostra de 151 empreses espanyoles de fabricació.

Els resultats mostren una relació quan les innovacions organitzatives són classificades com de procediment mentre no existeix aquesta relació quan són d'estructura.

Aquest és el primer estudi en la literatura que analitza aquesta relació a tots els nivells de qualitat i no només TQM. Per tant, els resultats són de gran valor per a directius a l'hora de prendre les decisions correctes abans i durant el procés d'implantació d'un sistema de gestió de la qualitat.

Abstract

The purpose of this study is to ascertain whether there is any correlation between the implementation of quality management systems (QMSs) in manufacturing firms and the use of certain organisational innovations in those firms.

Using the classification of organisational innovations proposed by Armbruster et al. (2008) and the various hierarchical levels of quality management suggested by Dale (2003), the study proposes and tests a series of hypotheses regarding the relationship between use of organisational innovations and level of quality management in an empirical study of 151 Spanish manufacturing companies.

The study finds a correlation between the level of quality management in an organisation and the implementation of procedural organisational innovations (at all levels of the organisation); however, no such correlation could be established with regard to the level of quality management and structural innovations.

This is the first study in the literature to analyse the relationship between organisational innovations and all types/levels of quality-management systems (not only TQM). The findings will assist managers to take appropriate strategic decisions when implementing QMSs.

6.1. Introduction

The relationship between quality-management systems and innovation has not received the research attention that it deserves; in particular, empirical studies of the relationship are rare (Prajogo and Sohal, 2003, 2006; Samson and Terziovski, 1999). Several theoretical studies have purported to analyse the relationship between quality management and innovative capacity in an attempt to ascertain whether organisations with a 'higher' level of quality management are also more innovative, especially in terms of the creation of new products and services. However, most of these studies, such as those by Llorens et al. (2003), Singh and Smith (2004), and Hoang et al. (2006), have been theoretical studies of organisations that have implemented total quality management (TQM), regardless of whether these firms have implemented other quality-assurance systems by means of management standards (such as the ISO 9001:2000 standard).

The few empirical studies that have been conducted have produced mixed findings. Some studies have reported a positive relationship between TQM and innovation; for example, a positive relationship has been reported between TQM and: (i) speed to market (Flynn et al., 1994); (ii) the number of new products offered to the market (Terziovski and Samson, 1999); and (iii) product innovation performance (Prajogo and Sohal, 2003). In contrast, other studies have found that TQM implementation actually reduces a company's innovating capacity (Singh and Smith, 2004). The latter finding confirmed theoretical studies that had suggested that TQM might actually hinder innovation in organisations (Slater and Narver, 1998; Kim and Marbougne, 1999; Baldwin and Johnson, 1996; Dow, 1999).

The explanation for these conflicting findings is likely to be the multi-factorial nature of both 'innovation' and 'quality management'. The notion of 'innovation' obviously involves a variety of activities—such as research and development (R&D), process development, design, marketing, organisational restructuring, resource management, and employee development (Mitra, 2000; Szeto, 2000). As such, researchers have measured ‘innovation’ with a wide variety of variables—including new products offered, number of patents created, new markets, new product variants, and even new production methods (Karagozoglu and Brown, 1998; Johannessen et al., 2001; Prajogo and Sohal, 2003). In view of the multiplicity of variables that can (and have been) used, it is obviously necessary to limit the scope of the concept of ‘innovation’ by choosing particular variables that suit the purposes of any given study. The present study seeks some degree of clarity in this regard by limiting its focus to the implementation of certain ‘organisational innovations’, as categorised by Armbruster et al. (2008).

Apart from the question of what constitutes ‘innovation’, clarity in this area is complicated by the question of what constitutes ‘quality’. Is innovation (defined for the present purposes as implementation of organisational innovations) related only to the implementation of TQM practices, as would appear to be inferred in the studies noted above, or can other forms of quality management also imply enhanced ‘innovation’? Several studies (Peris et al., 2001; Oackland, 2003, 2004; Kaynak, 2003, Camisón et al., 2007) have attempted to address the question of organisational innovations and quality management. However, these studies suffer from the same limitation that was noted above by focusing only on organisational innovations derived from TQM implementation. This fails to address the question raised above regarding the relationship between organisational innovations and various forms of quality management apart from TQM. The issue is significant because full-scale TQM is implemented in only a small number of organisations compared with the number of companies that opt for less exacting forms of quality management—such as quality assurance (QA) by means of implementing the ISO standard 9001:2000 (Marimon and Cristobal, 2005; Heras et al. 2006). The present study addresses this issue by considering other ‘levels’ of quality management, in accordance with the hierarchical classification proposed by Dale (2003).

Against this background, the present study seeks to establish whether a correlation exists between different levels of quality management and innovation (assessed in terms of the organisational innovations implemented by firms). In particular, the study examines this question within the context of manufacturing companies, which typically implement a greater number of relevant organisational innovations.

According to Miles (2005) the level of innovation and R&D investment among service firms is less, on average, than among manufacturing firms. In a similar vein, the most recent report on innovation in the services sector from the European Commission has stated that 32.17% of manufacturing companies have introduced process innovations whereas only 25.91% of small-and-medium service companies have done so (Hollanders and Kanerva, 2009).

The remainder of this paper is organised as follows. Following this introduction, a theoretical framework is presented in which the various types of organisational innovations and the various levels of quality management are defined. The subsequent section proposes a substantive hypothesis and several subordinate hypotheses regarding the relationship between levels of quality management and various types of organisational innovations. The paper then presents an empirical study in which these hypotheses are tested on a sample of more than 150 Spanish companies involved in commonly used quality-management systems. The results of the study and the implications of the findings are then presented. The paper concludes with a summary of the main findings and suggestions for further research.

6.2. Theoretical framework

6.2.1 Organisational innovation

Although Lam (2005) has noted that there is no absolute consensus on a definition of 'organisational innovation', the term is usually taken to refer to the use of new managerial and working concepts and practices (Damanpour and Evan, 1984; Damanpour, 1987).

On the basis of this working definition, several authors have proposed various classifications of 'organisational innovations'. Pardo del Val (2004) summarised the most important of these classifications in four main dimensions: (i) according to their scope (Marshak, 1993; Blumenthal and Haspeslagh, 1994; Van de Ven and Poole, 1995; Krüger, 1996; Ruiz and Lorenzo, 1999); (ii) according to their origin (Strebel, 1994; Appelbaum et al., 1998); (iii) according to their necessity (Beer and Eisenstat, 1996; Appelbaum et al., 1998); and (iv) according to their speed (Marshak, 1993; Blumenthal and Haspeslagh, 1994).

In terms of the dimension of 'origin', the present study focuses attention on the so-called 'reactive changes'. In other words, the focus is on organisational innovations that arise in response to a phenomenon in the environment (Appelbaum et al., 1998).

In terms of the dimension of 'scope', various authors (Whittington et al., 1999; Wengel et al., 2000; Coriat, 2001; Armbruster et al., 2008) have proposed that 'organisational innovations' should be classified as 'structural' or 'procedural'.

According to Armbruster et al. (2008, p. 646), structural organisational innovations are those that:

> … influence, change and improve responsibilities, accountability, command lines and information flows as well as the number of hierarchical levels, the divisional structure of functions, or the separation between line and support functions. Such structural organizational innovations include, for instance, the change from an organizational structure of functions into product- or customer-oriented lines, segments, divisions or business units.

On the other hand, Armbruster et al. (2008, p. 646) defined procedural organisational innovations as those that:

> … affect the routines, processes and operations of a company. Thus, these innovations change or implement new procedures and processes within the company, such as simultaneous engineering or zero buffer rules. They may influence the speed and flexibility of production or the quality of production.

Although these structural and procedural innovations can be either intra-organisational or inter-organisational (Armbruster et al., 2008), the present paper focuses only on intra-organisational innovations.

Some intra-organisational innovations are located in a specific department whereas others affect the overall structure of the company. Table 6.1 provides some examples of structural and procedural organisational innovations in the manufacturing sector—classified according to whether they affect the whole organisation (‘organisational level’) or whether they are more likely to occur in a specific department (‘sub-unit level’). This classification of exemplar ‘organisational innovations’ is adopted for the purposes of representing ‘innovation’ in the present study.

Table 6.1: A typology of organisational innovations in the manufacturing sector

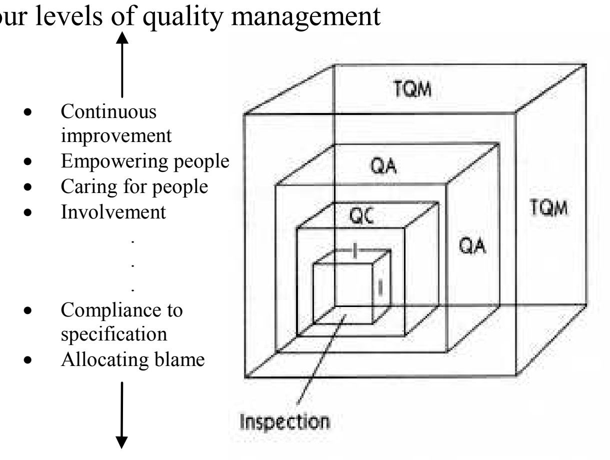
	Sub Unit Level	**Organisational level**
Structural innovations	Team work in production (manufacturing and assembly) Integration of tasks (planning, operating or controlling functions) Quality circles	Decentralisation of planning, operating and controlling functions Time bank for flexible labour capacity Manufacturing cells Cross-functional teams Reduction of hierarchical levels Virtual enterprise
Procedural innovations	Simultaneous/concurrent engineering Continuous improvement process (CIP) Preventive maintenance Job enrichment / job enlargement	Internal zero-buffer-principle (Kanban) Just-in-time delivery to the costumer (JIT) Supply chain management Outsourcing

Source: in-house compilation based on Armbruster *et al.* (2008)

6.2.2. Levels of quality management

According to Dale (2003), four 'levels of quality management' can be identified in any organisation: (i) quality inspection (QI); (ii) quality control (QC); (iii) quality assurance (QA); and (iv) total quality management (TQM). This hierarchical progression of quality management is illustrated in Figure 6.1.

Figure 6.1: Four levels of quality management



Source: Dale (2003)

The four 'levels of quality' can be characterised in note form as follows:

1. Quality inspection (QI): conformity evaluation by observation and judgment, accompanied (as appropriate) by measurement, testing, or gauging (ISO, 2005); QI provides information only with regard to end results; nothing is known about the process.
2. Quality control (QC): coordinated activities to direct and control an organisation with regard to quality (ISO, 2005); QC is thus the application of statistical process control (SPC) to manufacturing processes; it operates in a 'detection-type' mode (that is, finding and fixing mistakes).
3. Quality assurance (QA): a prevention-based system that improves product and service quality and increases productivity by emphasis on product, service, and process design; QA is the level achieved by an organisation after implementing a quality-management standard (such as ISO 9001:2000).
4. Total quality management (TQM): the application of quality-management principles to all aspects of the organisation, including customers and suppliers, and their integration with the key business processes (Dale, 2003); five practices can be said to define the concept of TQM: (i) customer focus; (ii) leadership and top management commitment; (iii) training and education; (iv) team; and (v) culture (Reed et al., 2000).

Among the eight quality management principles of the two main standards in the field of quality management (ISO 9000:2005 in quality assurance and EFQM in total quality management), certain principles can be identified—including 'costumer orientation', 'process approach', 'continuous improvement', and 'teamwork'—that are specifically related to the implementation of organisational changes in a firm. This suggests that a relationship might exist between the implementation of quality-management systems and organisational innovations. Hypotheses regarding this possible relationship are proposed in the following section.

6.3. Hypotheses

The following substantive hypothesis is proposed regarding the relationship between the 'level of quality management' and the implementation of 'organisational innovations' in the manufacturing sector:

– Hypothesis H1: There is a correlation between the level of quality management in an organisation and the use of organisational innovations.

In terms of the classification of organisational innovations of Armbruster et al. (2008), four subordinate hypotheses are proposed:

– Hypothesis H1a: There is a correlation between the level of quality management in an organisation and the use of structural innovations at the sub-unit level.

– Hypothesis H1b: There is a correlation between the level of quality management in an organisation and the use of procedural innovations at the sub-unit level.

– Hypothesis H1c: There is a correlation between the level of quality management in an organisation and the use of structural innovations at the organisational level.

– Hypothesis H1d: There is a correlation between the level of quality management in an organisation and the use of procedural innovations at the organisational level.

6.4. Methodology

6.4.1 Sample and data collection

Empirical data were collected from the Spanish sub-sample of the 2006 'European Manufacturing Survey' (EMS), which is a biannual international questionnaire that was first created by the Fraunhofer Institute for Systems and Innovation Research (ISI) in 1993 (Lay and Maloca, 2004).

Among other things, the EMS conducts a detailed study of the utilisation of organisational and technological innovations by manufacturing companies at both the intra-organisational and inter-organisational levels. In 2006, the EMS received approximately 3500 responses from 12 European countries (Austria, Croatia, France, Germany, Greece, Netherlands, Slovenia, Spain, Switzerland, Turkey, United Kingdom, and Italy).

The Spanish sub-sample of the survey consisted of manufacturing establishments (NACE codes 15–37) that have at least 20 employees. Approximately 10% of such Spanish firms (4450 surveys) received the EMS questionnaire, which was sent out by postal mail in two rounds (April 2006 and June 2006).

The final dataset for the present study consisted of 151 responses, which represented a response rate of approximately 3.5%. The relatively low response rate is likely to have been due to this being this particular survey's first run, and to the non-obligatory character of participation. Nevertheless, the responses had a confidence level of 83%, taking into account a margin of error of 5% (p=q=0.5).

6.4.2 Measures

Organisational innovations

The EMS surveys a set of organisational innovations, among which are several of interest in the present study (as previously listed in Table 6.1). The following organisational innovations from Table 6.1 were chosen for analysis on the basis of data from the EMS:

– Those relevant to subordinate hypothesis H1a (regarding the use of structural innovations at the sub-unit level): (i) 'teamwork in production'; and (ii) 'integration of tasks'.

– Those relevant to subordinate hypothesis H1b (regarding the use of procedural innovations at the sub-unit level): (i) 'simultaneous/concurrent engineering'; and (ii) 'continuous improvement process' (CIP).

– Those relevant to subordinate hypothesis H1c (regarding the use of structural innovations at the organisational level): (i) 'decentralisation of planning, operating, and controlling functions'; and (ii) 'time bank for flexible labour capacity'.

– Those relevant to subordinate hypothesis H1d (regarding the use of procedural innovations at the organisational level): (i) 'internal zero-buffer-principles' ('Kanban'); and (ii) 'just-in-time delivery to the costumer' ('JIT').

Levels of quality management

Although four levels of quality management had been defined by Dale (2003), an initial analysis of the available data in the present study suggested that the first two levels should be conflated, which produced the following three-level structure for this study:

– Group 1: quality inspection and quality control (QI & QC);

- Group 2: quality assurance (QA); and
- Group 3: total quality management (TQM).

It should be noted that this abridged classification has been used previously in the literature (Casadesús et al., 2005) and that the first two levels of Dale (2003) are actually closely related; indeed, they can be confused in practice. Organisations that have not yet established any quality-assurance system (such as the ISO standard 9001:2000) are commonly found in this conflated group (QI & QC).

It is acknowledged that Dale (2003) did differentiate the QI level from the QC level; however, this differentiation was not as distinct as that pertaining to the other levels. Indeed, Dale (2003) described QI and QC in similar terms. Thus, QI was described as the analysis of a product in order to know whether, at the end of the process, it satisfies the specifications in accordance with a simple conformity evaluation by observation, whereas QC was described in similar terms with the only difference being the nature of the conformity evaluation at the end of the process—which was described (in the case of QC) as incorporating somewhat more sophisticated methods and tools (such as statistical control).

In addition to these similarities between QI and QC in Dale's (2003) description, the rationale for conflating Dale's (2003) four levels of quality management into three also rests on the clear qualitative difference that exists between these two conflated levels (QI and QC) and the next level (QA). In QA, the focus is no longer on detection; rather, it is clearly on prevention. QA searches for the causes for the problems in order to analyse them and avoid similar failures in future (Juran 1974, 1988; Dale, 1994; Goetsch and Davis, 1994; James, 1996). This qualitative difference between QI and QC on the one hand and QA on the other makes the QA level quite different from the preceding levels. In other words, the difference between the QA level and the preceding levels of quality management is much more significant than the difference between the first two levels.

It was possible to assess the firms in the sample in terms of the proposed three-level schema on the basis of specific questions that had been included in the EMS questionnaire about the quality-management practices that exist in the responding firms. Firms had been asked directly about quality-control systems, implementation of quality-management standards, implementation of total quality management models, and so on. On the basis of the responses to these questions, it was possible to classify each organisation in the present sample in terms of the levels of quality management defined above. For example, an ISO 9001:2000-certified organisation implementing the EFQM model for TQM would be classified at the highest level of quality management in this study (Group 3, TQM). This general procedure was followed in classifying all the firms in the present sample into the three groups noted above.

In specific terms, the following criteria were applied to assess the level of quality management of each firm: (i) whether the firm had a quality management system (QMS) based on the EFQM model; (ii) whether the firm had implemented the ISO 9001 standard; (iii) whether the firm had an integrated quality-control process; and (iv) whether the firm had none of the above (which implied no quality control or minimal quality control by means of observation and judgment in association with some form of measurement, testing, or gauging of quality).

On the basis of these criteria, the firms were classified into the three groups noted above. A firm that had satisfied the first criterion was classified in the highest level of quality (Group 3: TQM). A firm that did not have a QMS based on the EFQM model but had implemented the ISO 9001 standard was classified in the second-highest group (Group 2: QA). The lowest level (Group 1: QI & QC) consisted of firms that had only a process-integrated quality control (classified as QC) and those that had no QMS (classified as QI).

6.5. Results

The results are presented in two groups. First, descriptive statistics and non-parametric analysis were used to draw some preliminary conclusions regarding the substantive hypothesis and the four subordinate hypotheses. Secondly, factor analysis and structural equation modelling (SEM) was used to propose and test a model linking the constructs of (i) 'structural innovation'; (ii) 'procedural innovations'; and (iii) 'level of quality management'.

6.5.1 Descriptive analysis

Levels of quality management

The levels of quality management in the sample were analysed in terms of: (i) the size of the firms; and (ii) their technological classification.

Table 6.2 shows the levels of quality management (Groups 1–3) in terms of the size of the companies in the sample. In general, companies with higher levels of quality management had greater numbers of employees and larger turnover. The second level of quality management (Group 2, QA) had the largest number of companies (72 of 151); in other words, just under 50% of the organisations had implemented a quality-assurance standard (usually ISO 9001:2000), but had not become involved in TQM.

Table 6.2: Levels of quality management and size of firms

Group	N	Employees	Turnover (M€)
1. Quality inspection & Quality control (QI&QC)	34	70	11,67
2. Quality Assurance (QA)	72	124	22,18
3. Total Quality Management (TQM)	45	156	29,57

Table 6.3 shows the levels of quality management (Groups 1–3) according to the OECD technological classification of the firms (OECD 2001). It is apparent that the companies were equally distributed in three of the four categories, but that there were only four companies in the high-technology classification.

Table 6.3: Levels of quality management and technological classification of companies

			Groups		
	NACE (total manufacturing, 15-37)	**N**	**1 (QI&QC)**	**2 (QA)**	**3 (TQM)**
Low-technology industries	Manufacturing, n.e.c.; Recycling (36-37) Wood, pulp, paper, paper products, printing and publishing (20-22) Food products, beverages and tobacco (15-16) Textiles, textile products, leather and footwear (17-19)	49	21 (42.9%)	15 (30.6%)	13 (26.5%)
Medium-low-technology industries	Building and repairing of ships and boats (351) Rubber and plastics products (25) Coke, refined petroleum products and nuclear fuel (23) Other non-metallic mineral products (26) Basic metals and fabricated metal products (27-28)	49	5 (10.2%)	27 (55.1%)	17 (34.7%)
Medium-high-technology industries	Electrical machinery and apparatus, n.e.c. (31) Motor vehicles, trailers and semi-trailers (34) Chemicals excluding pharmaceuticals (24) Railroad equipment and transport equipment, n.e.c. (352 + 359) Machinery and equipment, n.e.c. (29)	49	8 (16.3%)	28 (57.1%)	13 (26.5%)
High-technology industries	Aircraft and spacecraft (353) Pharmaceuticals (2423) Office, accounting and computing machinery (30) Radio, TV and communications equipment (32) Medical, precision and optical instruments (33)	4	0 (0.0%)	2 (50.0%)	2 (50.0%)
Total		151	34 (22.5%)	72 (47.7%)	45 (29.8%)

In general, the technology intensity of the organisations was correlated with a higher level of quality management. In the less technologically intensive sectors, the largest proportion of companies (42.9%) had the lowest level of quality management (Group 1, QI & QC). This proportion then gradually decreased in the more technologically intensive sectors; indeed, in the high-tech sector, there was no company with the lowest level of quality management (Group 1, QI & QC).

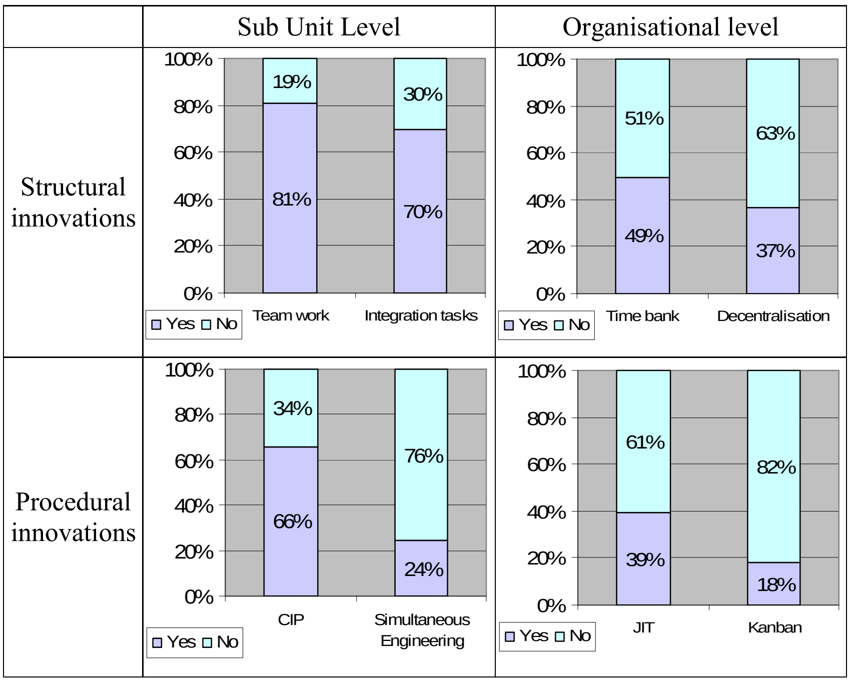
The two sectors of 'medium' technology intensity ('medium–low' and 'medium–high') were similar; in both cases, the majority of companies (57.1% and 55.1% respectively) had the second level of quality management (Group 2, QA). The highest level of quality management (Group 3, TQM) was achieved by 50% of firms only among those in the high-tech sector. However, these conclusions should be regarded with caution because the sample was relatively small and heterogeneous.

Use of organisational innovations

The use of organisational innovations in the sample was analysed in terms of: (i) their frequency of use; and (ii) their degree of use.

Figure 6.2 shows the frequency of use of the various organisational innovations in the entire sample. In general, the results in each quadrant of Figure 6.2 were similar (with the possible exception of 'procedural innovations' at the 'sub-unit level'), which indicates that the variables used in the study were reasonably representative of all quadrants, and thus suitable for testing the subordinate hypothesis applicable to each of the quadrants.

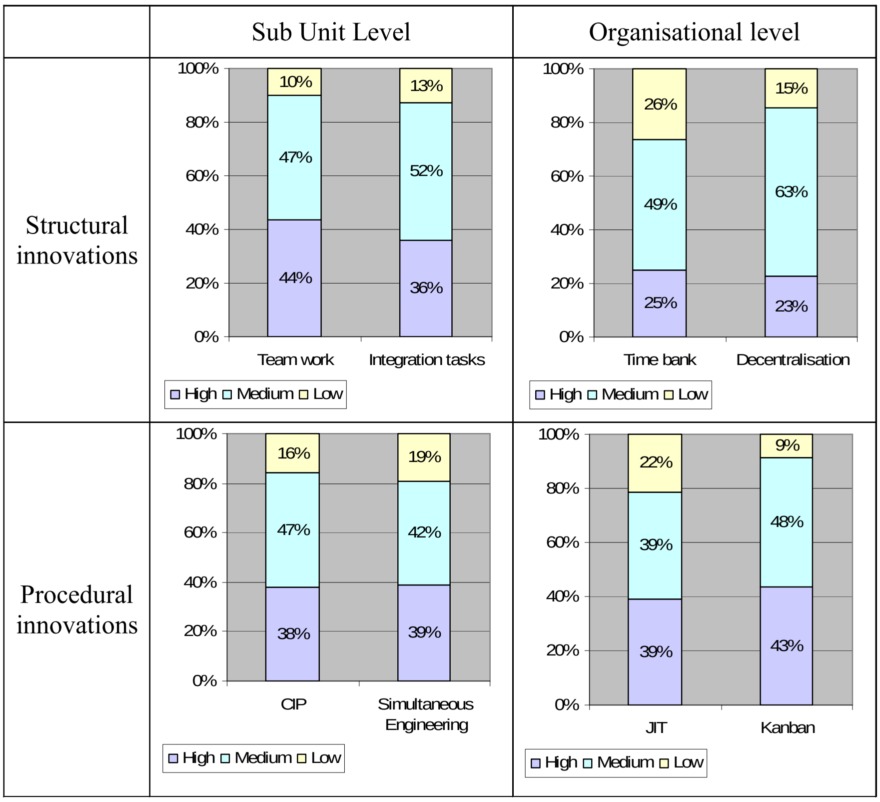
Figure 6.2: Frequency of use of organisational innovations



As shown in Figure 6.2, 'teamwork in production' was the most commonly used organisational innovation in the sample, with more than 80% of the companies having used it in production. The second-most commonly used was ‘integration of tasks’ (70%). It is noteworthy that both of these innovations are ‘structural innovations’ at the ‘subunit level’. In contrast, the least commonly used innovations were the ‘Kanban system’ (18%) and ‘simultaneous engineering’ (24%).

Figure 6.3 shows the degree of use (as distinct from the frequency of use) of the various organisational innovations in the entire sample. The innovation with the greatest degree of use was ‘teamwork in production’ (which was also the most frequently used), but the innovation with second-greatest degree of use was the ‘Kanban system’ (which had been in last place in terms of frequency of use). It is thus apparent that, although the ‘Kanban system’ was not widely established in terms of frequency of use across the whole sample, it had a high degree of use within the companies that had implemented it.

Figure 6.3: Degree of use of organisational concepts



Relationship between innovations and levels of quality management

The relationship between use of organisational innovations and level of quality management was analysed in terms of: (i) descriptive statistics; and (ii) the Wilcoxon–Mann–Whitney test.

Table 6.4 shows the means of frequency of use of each of the organisational innovations, according to the level of quality management (Groups 1–3). Each mean represents the number of organisations in each level of quality management that had adopted a particular innovation. The mean is expressed on a scale of 0 ('innovation used by no firms') to 1 ('innovation used by all firms'). For example, the table shows that a mean of 0.05 (5% of the companies) in the first level of quality management (QI & QC) had used the 'Kanban' system, whereas a mean of 0.13 (13% of firms) in the second level of management (QA) had used this innovation and a mean of 0.21 (21% of firms) in the third level of quality management (TQM) had used it.

Table 6.4: Means of use of organisational concepts per level of quality management

mean	**Group 1 (QI + QC)**	**Group 2 (QA)**	**Group 3 (TQM)**
Structural innovations at sub unit level			
Team work in production (manufacturing and assembly)	0.65	0.65	0.64
Integration of tasks (planning, operating or controlling functions)	0.44	0.53	0.53
Procedural innovations at sub unit level			
Simultaneous/concurrent engineering	0.07	0.21	0.16
Continuous improvement process	0.18	0.51	0.66
Structural innovations at organisational level			
Decentralisation of planning, operating and controlling functions	0.20	0.26	0.27
Time bank for flexible working hours	0.31	0.29	0.41
Procedural innovations at organisational level			
Internal zero-buffer-principle (Kanban)	0.05	0.13	0.21
Just-in-time delivery to the costumer	0.20	0.28	0.39

According to the results in Table 6.4, it is apparent that a general correlation existed between the use of an innovation and the level of quality management of the firms; for example, the mean for 'JIT' use increased progressively with higher levels of quality management. However, there were exceptions to this general rule; for example, 'time bank for flexible working hours' had less use among Group 2 firms (QA) than among Group 1 firms (QI & QC), 'simultaneous engineering' had greatest use among Group 2 firms (QA), and 'teamwork in production' had no correlation between use and the level of quality management in the companies.

In terms of the substantive hypothesis, these preliminary analyses suggest that greater use of organisational innovations did occur in companies that had a higher level of implementation of quality systems. To analyse this preliminary conclusion in greater depth, a comparison of means among the various quality-management groups was conducted using the Wilcoxon–Mann–Whitney test (assuming that the variables did not follow a normal distribution). For each of the eight organisational innovations, contrasts were assessed among the three groups of quality management (assuming a null hypothesis that there was no difference of means among the groups). The results are shown in Table 6.5.

Table 6.5: Wilcoxon–Mann–Whitney comparison of means of quality innovations among levels of quality management

p-value among groups	**Groups 1-2**	**Groups 1-3**	**Groups 2-3**
Structural innovations at sub unit level			
Team work in production	0.699	0.766	0.496
Integration of tasks (planning, operating or controlling functions)	0.267	0.330	0.921
Procedural innovations at sub unit level			
Simultaneous/concurrent engineering	0.355	0.175	0.024*
Continuous improvement process	0.000*	0.000*	0.064
Structural innovations at organisational level			
Decentralisation of planning, operating and controlling functions	0.468	0.397	0.821
Time bank for flexible working hours	0.638	0.292	0.102
Procedural innovations at organisational level			
Internal zero-buffer-principle (Kanban)	0.166	0.012*	0.114
Just-In-Time delivery to the customer	0.220	0.023*	0.141

In terms of the substantive hypothesis, although the previous results (see Table 6.4) had suggested that a general correlation did exist between level of quality management and the use of organisational innovations, the results of the Wilcoxon–Mann–Whitney test (see Table 6.5) revealed significant differences ($p < 0.05$) among quality-management groups for only half of the innovations. The innovations that showed such a significant difference were 'simultaneous engineering', 'continuous improvement process', 'internal zero-buffer-principle' ('Kanban'), and 'JIT'. All of these had been classified as procedural innovations. For all other innovations, no clearly significant differences were detected in terms of level of quality management (Groups 1–3).

With respect to the first subordinate hypothesis (H1a), which proposed that the level of quality management is correlated with the use of structural innovations at the sub-unit level, the data regarding the innovations of 'teamwork in production' and 'integration of tasks' revealed that these were two of the more common innovations among companies, irrespective of their level of quality management. An analysis of the differences between means using the Mann-Whitney test confirmed the null hypothesis that there were no significant differences among the various groups of quality management. The first subordinate hypothesis (H1a) is therefore rejected.

With respect to the second subordinate hypothesis (H1b), which proposed that the level of quality management in a company is correlated with the use of procedural innovations at the sub-unit level, the data regarding the innovations of 'simultaneous/concurrent engineering' and 'continuous improvement process' (CIP) showed significant differences. In the case of CIP, significant differences were detected between the first group (QI & QC) and the other two groups (QA and TQM); however, no significant differences were detected for this innovation between the second group (QA) and the third group (TQM). These results suggest that this innovation was significantly more likely to be used in companies that had achieved the second quality level (QA). In contrast, a significant difference in the use of 'simultaneous/concurrent engineering' was found between the second group (QA) and the third group (TQM). In conclusion, the null hypothesis must be rejected and subordinate hypothesis H1b is accepted.

With respect to the third subordinate hypothesis (H1c), which proposed that the level of quality management in the company is correlated with the use of structural innovations at the organisational level, the innovations of 'decentralisation of planning, operating and controlling functions' and 'time bank for flexible labour capacity' were analysed. Significant differences were not detected among the three groups of levels of quality management. The null hypothesis must therefore be accepted, and subordinate hypothesis H1c must be rejected.

Finally, with respect to the fourth subordinate hypothesis (H1d), which proposed that the level of quality management in the company is correlated with the use of procedural innovations' at the organisational level, the innovations of 'internal zero-buffer-principle' ('Kanban') and 'just-in-time delivery to the customer' were analysed. Differences were found for both of these innovations between the first (QI & QC) and third (TQM) groups of quality management. A possible explanation might be that neither innovation was used until the highest quality levels had been reached by the companies. The null hypothesis of equality of means must therefore be rejected, and subordinate hypothesis H1d is accepted.

As a result of these findings with regard to the four subordinate hypotheses, it can be concluded that the substantive hypothesis should be rejected when referring to 'structural innovations', but accepted in the case of 'procedural innovations'.

6.5.2 Factor analysis and proposed model

Factor analysis

An exploratory factor analysis was conducted to identify the dimensions derived from the data of the study. The matrix of correlations was submitted to two tests: Bartlett's sphericity test and the Kaiser-Meyer-Olkin (KMO) index. The Bartlett statistic, with a value $\chi 2$ = 144.52 (significance level of 0.000), confirmed the existence of linear dependence between the variables, and thus justified continuing with the procedure. The KMO (0.767) also confirmed that factor analysis was likely to generate satisfactory results (Visauta, 1998). The analysis extracted two factors. The Kaiser criterion was used to retain only those factors that presented eigenvalues of one or greater. These first two factors retained 47.0% of the initial variance, which represented a good proportion in view of the fact that each of the new components provided independent (and therefore unrepeated) information.

Table 6.6: Exploratory factor analysis of organisational innovations

	Component	
Items	**Structural innovation**	**Procedural innovation**
Integration	.720	
Time bank	.681	,177
Team work	.632	,192
Decentralisation	.593	,118
Simultaneous	.504	
JIT		.830
Kanban	,257	.701
CIP	,289	.583

Extraction method: Main components analysis
Rotation method: Varimax normalization with Kaiser
Rotation converged in 3 iterations

Using the varimax rotation method, weightings were obtained for each factor in each of the variables (see Table 6.6). It is apparent that all items (individual organisational innovations) correlated strongly with one or other dimension ('structural' or 'procedural').

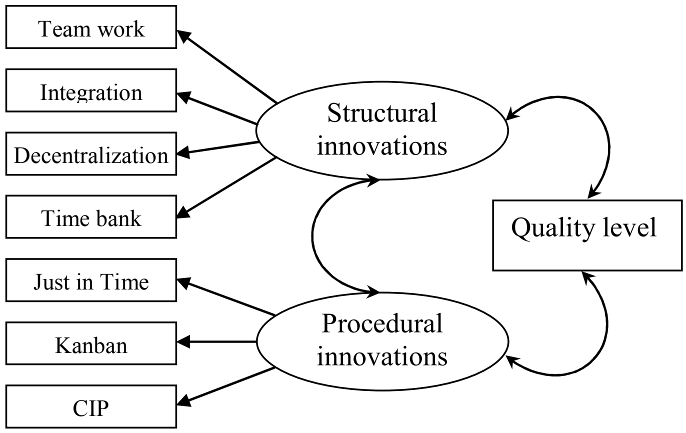
Apart from one exception, these results coincided with the classification suggested by Armbruster et al. (2008) (as previously shown in Table 6.1). The exception was 'simultaneous engineering', which had been situated among 'procedural innovations' by Armbruster et al. (2008) but appeared among 'structural innovations' in the present results. However, it should be noted that the loading for this item on the dimension of 'structural innovations' was only moderate and that the correlations with the other items loading on this dimension were poor (correlation between this item and the total corrected subscale was 0.303). In accordance with the criteria suggested by Sanzo et al. (2003), it was decided to discard this item from further analysis.

Having eliminated the aberrant item, the reliability of the resulting two constructs was assessed using Cronbach's alpha. The construct of 'structural innovations' had a Cronbach's alpha of 0.617, which exceeded Malhotra's (2004) minimum criterion of 0.6 for demonstrating internal consistency. The construct of 'procedural innovations' had a Cronbach's alpha of 0.531. Although this suggested some doubt about the reliability of the second construct, the analysis proceeded (albeit with caution regarding any final conclusions thus obtained).

Proposed model

Drawing on the results of the study, Figure 6.4 shows a proposed model of the relationships among organisational innovations (represented by the constructs of 'structural innovations' and 'procedural innovations') and the level of quality management of organisations.

Figure 6.4: Proposed model of organisational innovations and level of quality management



6.5.3 Size control variable

Table 6.2 raised some concerns that needed to be addressed before continuing the analysis. A possible interpretation of Table 6.2 is that that the larger the size of the firm, the higher the level of quality attained. It was therefore appropriate to control for the possible effect of firm size before testing the model.

Given that the proposed model does not include any directional pathways between constructs (because, at this point, there is no evidence of causality between constructs), it was not possible to include a control variable of 'size of firm'. Therefore, to conduct an analysis that effectively controls for the effect of company size, a variation of the model proposed in Figure 6.4 was tested. In this variation, the dependent variable was 'quality' and the independent variables were the innovation constructs and an additional construct that reflected size. For the latter, the natural logarithms of the total number of employees and turnover were used as indicators of company size; this was in accordance with López et al. (2008), who used a similar measure for company size.

An explanatory factor analysis was then conducted, employing the principal components method, with the items of innovation and the two indicators of company size. One of the factors included the two size indicators as a single measure of company size. Both had high loads (greater than 0.9) and Cronbach's alpha for this factor was 0.904 (which confirmed reliability).

To conduct this control analysis, a binary logistic regression was performed, in which the dependent variable was the level of quality. This was considered 'low' for the companies in groups 1 and 2 in Table 6.3, and 'high' for those in group 3. The dependent variables were three constructs that were formed in the previous factorial analysis: (i) the factor formed by the size indicators; (ii) the four structural innovation items; and (iii) three of the four procedural innovations items (with 'simultaneous engineering' being removed because it loads on the second and third factor).

In accordance with the methodology of López et al. (2008), a hierarchical regression analysis was performed. The forward-step of the Wald method was chosen. The R2 statistic of Nagelkerke was 0.072, which is acceptable, and the prediction accuracy was 68.6%. The only variable that remained in the model was the procedural innovation factor, with a significance of 0.013. The structural innovation construct and size construct were excluded. The company size did not have a significant effect on the level of quality attained.

6.5.4. Hypothesis testing

To test the model, structural equation modelling (SEM) was performed using the maximum-likelihood method on EQS software. The comparative fit index (CFI) was 0.998. The chi-square based on 18 degrees of freedom was 18.27 ($p = 0.4378$). GFI (0.970) and AGFI (0.939) confirmed that the data fitted the model.

As shown in Table 6.7, all loadings of the innovation items were significant ($p > 1.96$ for all items). Moreover, two of the three correlations between constructs in the model were significant: (i) a correlation between 'structural innovations' and 'procedural innovations'; and (ii) a relationship between 'procedural innovations' and 'level of quality management'. However, no such relationship could be established between 'structural innovations' and 'level of quality management'.

Table 6.7: Correlations between innovation constructs and levels of quality management

	Covariance	p-value
Structural innovation – Procedural innovation	.473	3.509*
Structural innovation – Quality level	.033	.286
Procedural innovation – Quality level	.630	3.644*

* indicates that the p-value is significant at .05 ($p > 1.96$)

These findings confirmed the findings of the non-parametric analysis. Subordinate hypotheses H1b and H1d (which both referred to procedural innovations) are therefore accepted, irrespective of whether these innovations occur at the 'sub-unit' level or 'organisational' level. In contrast, subordinate hypotheses H1a and H1c (which both referred to structural innovations) are rejected—because no correlation between level of quality management and 'structural innovations' was detected in the model.

The results might suggest that 'procedural innovations' represent an intermediate construct between levels of quality management and 'structural innovations'; that is, perhaps the 'procedural innovations' that are emphasised by such quality standards as ISO 9001:2000 receive attention in organisations before the so-called 'structural innovations' that are associated with full-scale models of TQM. However, there is no empirical evidence apparent in the literature in support of this proposition.

6.6. Conclusions

The aim of this study was to ascertain whether a relationship exists between the level of quality management in an organisation and the implementation of organisational innovations To assess this possible relationship, the study has utilised the classification of organisational innovations proposed by Armbruster et al. (2008) and the levels of quality management defined by Dale (2003). There is apparently no empirical study of these issues in the extant literature, apart from some studies relating to the establishment of total quality management (TQM). However, full-scale TQM models are implemented much less frequently than the various quality-assurance systems and standards (such as ISO 9001:2000) (Heras et al., 2006). Indeed, the present study has demonstrated that the majority of sample companies were situated in only the second level of quality management (defined as 'quality assurance' in this study), without having opted for TQM. It is thus apparent that empirical research into the relationship between organisational innovations and other levels of quality management (apart from TQM) is required. The present study has attempted to address this need.

The conclusions of the study can be summarised as follows. First, the study has established that, in general, the implementation of 'organisational innovations' is generally associated with a higher level of quality management, especially in companies with greater numbers of employees and larger turnover. More specifically, higher levels of quality management in an organisation were correlated with greater use of organisational innovations of a 'procedural' type (at every level of the organisation), whereas no significant correlation was detected regarding innovations of a 'structural' type. Although these findings might have been expected in organisations that have implemented only the lower levels of quality management (quality inspection and quality control), it is noteworthy that similar findings were apparent in the companies involved in the highest level of quality management (TQM).

Secondly, the present study failed to detect any differences in the results in terms of the 'sub-unit level' or the 'organisational level' of the sample firms. It is apparent that the level of quality management and the organisational innovations were implemented uniformly across the whole organisation.

It is acknowledged that the use of only two items to analyse each type of organisational innovation ('structural' and 'procedural') is a limitation of the study. It is obviously desirable to expand on the present findings in this regard. Having established the general tendency of these two types of innovations in relation to various levels of quality management, it would be interesting to conduct a field study that focuses more specifically on each kind of organisational innovation using a wider variety of particular innovations for analysis.

Another acknowledged limitation in the present study arises from the structure of the EMS questionnaire. The particular categorisation used in that questionnaire to assess quality level has been transformed for application in the database of the present study to enable testing of the model in accordance with the categorisation of innovation suggested by Armbruster et al. (2008).

It is also acknowledged that the differentiation assumed in this study between 'quality management' and 'organisational innovation' might not be readily accepted by all researchers in this subject area. Indeed, some authors contend that 'quality management' is, in itself, a form of 'organisational innovation'. However, many others insist that the two concepts should be differentiated (Singh and Smith, 2004; Slater and Narver, 1998; Kim and Marbougne, 1999; Baldwin and Johnson, 1996; Dow, 1999). Most of these authors suggest that the implementation of TQM actually reduces or hinders innovation, and that 'quality management' and 'organisational innovation' should therefore be considered as separate concepts. It is also of interest that the European Manufacturing Survey requires that information on 'organisational innovation; and 'quality level' be provided separately. The present study adopts the view that differentiating between these concepts is justified.

This paper provides empirical support for: (i) the theories proposed by Llorens et al. (2003) and Hoang et al. (2006), that quality is related to the adoption of innovations by organisations; and (ii) the levels of quality management suggested by Dale (2003).

Finally, as noted above, the present findings provide a basis for suggesting that 'procedural innovations' might represent an intermediate construct between levels of quality management and 'structural innovations'. It is possible that the emphasis placed on 'procedural innovations' by such commonly used quality standards as ISO 9001:2000 has caused organisations to implement this type of organisational innovation before they implement the so-called 'structural innovations' that are associated with full-scale models of TQM.

From the perspective of practitioners, the results suggest that the path towards total quality has to start with the implementation of procedural innovations, followed by structural innovations. However, this conjecture requires further investigation.

Summary & Future research

The five essays of this dissertation explore the use of innovation management strategies and the implementation of technological and non-technological innovations to have an impact on a firm's competitiveness. They approach the concept of innovation from both a technological perspective and a more holistic one.

The first essay, "Exploring barriers to R&D cooperation in the Spanish manufacturing sector", has two main objectives. First, it provides a new framework to classify technology firms according to two dimensions: R&D activity and product strategy. Second, it empirically examines the relationship between the technological pattern of firms and R&D cooperation, specifically the barriers encountered to engage in R&D cooperation.

The new framework raises again the need to account for the multidimensionality of technological intensity (e.g. Grinstein and Goldman, 2006), and to consider several patterns of technological intensity (e.g. Pavitt, 1984; Tidd et al., 2001; Souitaris, 2002). This means that policies applied to firms according to unidimensional criteria, such as the National Classification of Economic Activities code or single R&D proxies, may not capture the technological options and requirements of firms, and therefore are more likely to fail. Moreover, the fact that industries from the same sector do not cluster in a single group indicates that technological pattern is more a strategic option than an imperative within a sector.

On the other hand, barriers to cooperation are generally related to intra-firm characteristics, associated with an insufficient technological level. For firms with higher levels of technology, these barriers lose importance, and the inter-partner barriers become more important. When the cooperation partners are universities, executives pointed to weaknesses internal to universities and ,mainly, their unresponsiveness to industry needs.

The second and third essays are two empirical works about the strategic attitudes and the success drivers of T/C Spanish firms to keep their competitiveness confronted with the liberalisation of the market.

The second essay, 'Strategic attitudes in the global textiles market: the case of a South European cluster', is based on the strategic typology defined by Miles and Snow (1978) and explores the technological profile of twelve firms in order to understand the key issues for companies' survival. According to the seven dimensions analysed (current strategic focus, desired strategic focus, R&D intensity, R&D type, R&D outsourcing or collaboration, specific technological needs and general technological needs), most of the firms studied are classified as defenders, the most protective attitude. Moreover, the results point out the coincidence of both profile and subsector firms, in such way that the cotton spinning firms tend to be classified as defenders, while fibre spinning firms are analysers, defined as "followers".

The third essay, "What are the success factors for Spanish textile firms? An exploratory multiple-case study", explores four possible dimensions to explain the differential traits of twelve high-performing (HP) versus average-performing (AP) firms in the T/C sector: knowledge generation and acquisition, innovation activity, product and market characteristics and strategic characteristics.

The main finding is that the differentiating dimension of successful firms is innovation activity. HP firms consider innovation as a strategic priority, and that priority requires a focus strategy rather than a whole market strategy. In particular, some subsectors seem to be more suitable for some strategic profiles according their distribution represented in Figure 3.3. For instance, the cotton spinning subsector due to its nature to compete with low workforce prices and long standard productions fits with the defender-reactor profile while the fiber-spinning subsector fits better with a more leadership profile as the prospector.

In addition, the limited dimension of these firms is better suited to a niche or focus strategy, which goes along with a small market. The contribution of these two empirical essays is clearly policy oriented. Policy makers take into account that strategic attitude is a key issue when faced with an increasingly competitive environment, especially in the case of the low-tech industries that represent most growth and employment in the OECD countries.

The era of competing with low-cost production ended with market liberalisation and the arrival of competitors from countries with lower labour costs. Policy makers should therefore steer policies in the direction of helping firms to change their technological attitudes to more prospector ones and creating healthy environments through innovation supporting infrastructures. For instance, the creation of clusters would favour cooperation among firms, suppliers and costumers and spread added value to all the agents across the value chain. Moreover, the importance of these results is that they could probably be extended to traditional manufacturing sectors other than the T/C sector.

The fourth essay, ‘The use and impact of technologies in factory environments. Evidences from a manufacturing survey in Spain’, is focused on the implementation of advanced manufacturing technologies (AMTs) in Spanish manufacturing companies. Its contribution is twofold. First, detailed and descriptive data on the current and future use of AMTs in Spanish manufacturing firms are presented, and second, a model is proposed to expand understanding of how only a complete implementation has impact on performance rather than a partial implementation of AMTs.

In reference to the sample, the most widely implemented technologies are CAD followed by ERP and industrial robots. On the other hand, when the focus is on the level of usage, the most commonly implemented technologies are CAD-CAM, ERP and industrial robots. Looking to the future, the technologies featured most commonly in plans for implementation over the course of the next two years are ERP, computer-controlled warehousing and industrial robots.

The model presented in this work provides evidence that the implementation of new technologies within a firm does not have a positive impact on performance until the implementation is complete. However, taking into account the future plans for implementation mentioned above, specific policies might be drawn up to help firms acquire and completely implement these technologies.

Finally, in the last essay, 'Relationship between quality management systems and organisational innovations', the use of organisational innovations in Spanish manufacturing firms is revisited to ascertain whether there is any correlation between the implementation of quality management systems (QMSs) and the use of certain organisational innovations in those firms.

Organisational innovations are classified into 'procedural and structural organisational innovations' according the taxonomy proposed by Armbruster et al. (2008). This is the first study in the literature to analyse the relationship between these organisational innovations and all levels of quality management systems proposed by Dale (2003).

The study discovers a correlation between the level of quality management in an organisation and the implementation of 'procedural organisational innovations'; however, no such correlation could be established with regard to the level of quality management and 'structural' innovations. A conceptual model of the relationships among the constructs of 'structural innovations', 'procedural innovations', and level of quality management is proposed and tested.

The findings provide a basis for suggesting that 'procedural innovations' might represent an intermediate construct between levels of quality management and 'structural innovations'. It is possible that the emphasis placed on 'procedural innovations' by such a commonly used quality standard as ISO 9001:2000 has caused organisations to implement this type of organisational innovation before they implement the so-called 'structural innovations' that are associated with full-scale models of TQM. The findings might help managers take appropriate strategic decisions when implementing QMSs.

To sum up, the overall objective of the thesis is to shed some light on innovation strategy and management in specific sectors particularly important for the country of Spain and on technological and organizational patterns in the field of innovation in production. The first three essays deal with innovation strategy and management in low and medium technology (LMT) sectors of the Spanish manufacturing industry, particularly the textile and clothing (T/C) sector which is the core of the analysis of the second and third essay. The last two essays are related to the question of technological and organizational process innovations in manufacturing environments, using data of a survey of 151 manufacturing companies in Spain.

The main objective of the three first essays is to contribute to a better understanding of innovation strategy patterns in low and medium technology industries. This is a very important, but often under-investigated topic, because low and medium technology industries still represent large shares of the European GDP and jobs in manufacturing, but research tends to focus more on the sometimes over-hyped high technology (HT) industries. Thus, the thesis wants to emphasize the importance of this piece of research to try to get further insights in the patterns and processes of innovation strategy and management in low technology (LT) firms.

The second main objective of the thesis, materialized in the fourth and fifth essays is to analyse how manufacturing firms are setting up technological and organizational process innovations and how these structural and procedural innovations, which are often underexposed compared to the mostly dominating product innovations, contribute to a superior performance of manufacturing companies.

Although the overall scope of the dissertation is broad and challenging it tries to focus on some specific topics. The relevance of the work for academia as well as practitioners should be high, as it tries to provide some deeper insights into some of the neglected areas of innovation and production research: innovation strategy patterns in low and medium technology (LMT) firms, which are still very important for the European economy, and technical and organizational process innovations in manufacturing firms, which are often overshadowed by the main focus on product innovations in innovation research. The findings can be of use to modelate some theory and also to inform better policy-makers on the strengths, weaknesses and processes of LMT firms. Therefore, this dissertation tries to open up the view on some relevant and so far under-researched areas of the innovation landscape.

Future research

Despite the evidence presented above, much work can still be done to address gaps in the innovation field. My academic career has helped me to completely understand that the innovation concept is more complex than I would have ever thought. At this point I would compare the term innovation with a big umbrella under which many other technological, non-technological and strategic terms can be found.

Hence, the fuzziness of the innovation concept gives me the chance to explore many exciting gaps because quantifying, evaluating and benchmarking innovation competence and practice is a significant and complex issue for many organisations these days (Frenkel et al., 2000).

I confirm my willingness to continue the study of the implementation of technological, non-technological and strategic innovations, particularly with the desire to know more about the effectiveness of innovation actions in a wider geographical area.

In 2010 the collection and treatment of data from the second round of the European Manufacturing Survey in Spain will not only allow a dynamic analysis of the data with data gathered in 2006, but also a cross-national analysis with the thirteen other countries that will take part in the survey.

A generalised measurement framework, specific to the level of the organisation and not only for Spain, would provide a useful way for managers to monitor and evaluate their innovation processes, diagnose limitations and prescribe remedies (Cebon and Newton, 1999).

To conclude, future activities seem to be oriented towards analysing empirical evidence of the evolution of the use of innovation-related concepts in order to determine which aspects strengthen a firm's competitiveness, so necessary in these turbulent times.

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Appendix

Appendix 2.A: Correlation matrix among the characteristics (Spearman's rho)

		1	2	3	4	5	7	8	10	12	15	18
1	Relative R&D investmet level	1.000										
2	Relative number of R&D personnel	0.352**	1.000									
3	Outsourcing R&D	-0.352**	-0.086	1.000								
4	Emphasis on applied R. Vs D.	0.417**	0.358**	-0.551**	1.000							
5	Management comittment to R&D	0.120	0.146	0.014	0.034	1.000						
7	Number of products and their innovativeness	-0.043	0.144	0.007	-0.191	0.215	1.000					
8	Products with a short life cycle	-0.150	0.135	0.253	-0.002	0.026	0.091	1.000				
10	Ill-defined market needs	0.245	0.353**	0.024	0.096	0.280*	-0.055	-0.077	1.000			
12	Management attitude towards change	0.232	0.306*	-0.293*	0.425**	-0.040	-0.225	-0.112	-0.048	1.000		
15	Use of cross-functional teams in R&D	0.018	0.086	-0.022	0.080	0.146	0.165	-0.031	0.119	-0.036	1.000	
18	Incentinve and group-based reward systems	0.180	0.150	-0.260*	0.125	-0.056	0.212	-0.007	0.150	0.184	-0.020	1.000

*, ** Correlation is significant at the 0.05 and 0.01 (two-tailed) respectively.

Appendix 2.B: MDS analysis distance table

Variable	x	y
R&D_exp	1,4567	0,0818
R&D_pers	0,2393	-0,2044
R&D_out	-2,5612	0,5563
AppR_Dev	1,4562	-0,2542
Commit_R&D	-0,2499	0,9572
New_prod	-1,0071	-0,6943
Life_cycle	-1,2236	-0,8543
Mk_need	0,0661	0,8431
Att_change	1,571	-0,4289
Teams	-0,409	1,0097
Rew_sys	0,6614	-1,0121

Firm	x	y
H_Optical1	-1,7577	-0,5703
L_Food1	-0,4167	0,3797
L_Food2	1,5489	-0,821
L_Food3	-1,1984	-0,8333
L_Food4	-0,8506	-0,142
L_Man1	-0,4342	0,5045
L_Man2	1,9249	-0,585
L_Man3	-0,1959	-1,2567
L_Man4	-0,8296	2,2043
L_Man5	-1,3933	-0,3339
L_Man6	-1,4351	0,6732

Firm	x	y
L_Pap1	-1,2011	-0,0589
L_Pap2	-0,5927	0,3303
L_Pap3	0,3969	0,4601
L_Tex1	-0,6297	0,1824
L_Tex2	-0,7107	0,3528
L_Tex3	-1,2216	-0,674
L_Tex4	0,0841	0,3276
L_Tex5	-0,7848	0,6047
L_Tex6	-0,3446	0,3943
MH_Chem1	0,032	-1,1857
MH_Chem2	-1,2035	0,6203
MH_Chem3	2,3625	-1,3706
MH_Chem4	2,2475	0,2185
MH_Chem5	-0,6501	0,1246
MH_Chem6	1,7145	-0,9841
MH_ElMach1	-0,5728	1,2562
MH_ElMach2	0,493	0,2025
MH_ElMach3	1,991	0,1507
MH_ElMach4	0,5477	2,2405
MH_Mach1	0,5425	1,1614
MH_Mach2	1,3375	-1,0383
MH_Mach3	-0,2221	0,2744
MH_Mach4	-0,7349	0,3756
MH_Mach5	0,9339	1,1933

Firm	x	y
MH_Mach6	1,9358	-0,6668
MH_Vehicle1	0,9666	-0,45
MH_Vehicle2	0,9354	1,1796
ML_BMet1	-0,1082	-0,0401
ML_BMet2	-1,2688	-0,7125
ML_Met1	-1,5175	-1,4847
ML_Met2	-0,4102	1,1732
ML_Met3	-0,9122	-1,1382
ML_Met4	-0,5047	-0,8585
ML_Met5	0,7214	0,1963
ML_Met6	-0,0899	-1,4979
ML_Met7	-0,362	0,3733
ML_Met8	-0,0211	-0,3156
ML_NMet1	-0,447	-0,0467
ML_NMet2	0,8761	-1,9073
ML_NMet3	-1,5615	-1,6224
ML_Plas1	-0,5031	-0,1145
ML_Plas2	0,698	0,7256
ML_Plas3	-0,0274	0,8055
ML_Plas4	2,1642	1,0791
ML_Plas5	-0,3981	0,7702
ML_Plas6	-0,5593	-0,7988
ML_Plas7	2,0077	0,1478
ML_Plas8	-0,4059	0,8248

Appendix 2.C: Description of the 59 firms of the sample

Industry	Employees	Age of the unit (years)	Turnover (M€)	Exports (% of sales)	R&D expenditures as a percentage of sales
HIGH TECHNOLOGY INDUSTRIES					
Medical, precision and optical instruments					
– Firm 1 (testing tools)	160	71	25.799	30	0,8
MEDIUM-HIGH TECHNOLOGY INDUSTRIES					
Chemicals excluding pharmaceuticals					
– Firm 1 (inorganic)	110	17	18.000	40	-
– Firm 2 (plastic raw)	70	141	4.800	30	0,5
– Firm 3 (pharmaceutic preparation)	115	36	13.800	30	11
– Firm 4 (soup)	60	54	15.000	5	2,35
– Firm 5 (perfume)	180	24	21.000	40	-
– Firm 6 (other chemical products)	150	118	26.999	18	3
Electrical machinery and apparatus, n.e.c.					
– Firm 1 (electric controls)	150	8	12.000	0	5
– Firm 2 (cables)	50	17	12.000	45	5
– Firm 3 (accumulators)	240	27	29.999	22	4
– Firm 4 (other electrical machinery)	32	18	2.640	10	14
Motor vehicles, trailers and semi-trailers					
– Firm 1 (motor vehicles)	160	24	15.000	10	3,5
– Firm 2 (non-electrical pieces)	24	17	9.654	25	5
Machinery and equipment, n.e.c.					
– Firm 1 (valves)	110	19	18.000	50	5
– Firm 2 (refrigeration)	110	38	8.484	35	3
– Firm 3 (machinery - tool)	90	25	8.172	75	2
– Firm 4 (machinery - tool)	182	38	17.400	30	2,5
– Firm 5 (metal industry machinery)	50	18	6.600	75	5
– Firm 6 (construction machinery)	135	53	41.999	55	3
MEDIUM-LOW TECHNOLOGY INDUSTRIES					
Rubber and plastics products					
– Firm 1 (plastic tube)	40	35	21.000	15	0,5
– Firm 2 (other plastic products)	180	18	18.000	25	4,5
– Firm 3 (other plastic products)	60	14	10.482	50	1,1
– Firm 4 (other plastic products)	47	17	6.150	45	0,65
– Firm 5 (other plastic products)	130	39	15.600	25	2
– Firm 6 (other plastic products)	50	8	6.000	0	5
– Firm 7 (other plastic products)	48	21	9.000	30	5
– Firm 8 (other plastic products)	102	7	9.984	97	1
Basic metals and fabricated metal products					
– Firm 1 (cold lamination)	45	35	9.582	8	0,5
– Firm 2 (aluminium transformation)	45	24	21.000	5	0
Other non-metallic mineral products					
– Firm 1 (bathroom fittings)	130	35	12.000	45	0,4
– Firm 2 (concrete elements)	150	24	35.999	0	4
– Firm 3 (concrete elements)	35	22	4.800	0	0
Fabricated metal products, except machinery eand equipment					
– Firm 1 (metallic structures)	30	19	11.982	0	0
– Firm 2 (metallic structures)	65	21	8.484	1	0,2
– Firm 3 (tanks)	45	8	2.244	4	0
– Firm 4 (cutlery)	47	33	6.000	50	-
– Firm 5 (machinery tools)	110	23	17.400	35	2,15
– Firm 6 (machinery tools)	50	19	6.000	85	0,5

– Firm 7 (other metal products)	65	40	7.800	30	2
– Firm 8 (other metal products)	116	34	16.800	50	0,7
LOW TECHNOLOGY INDUSTRIES					
Manufacturing, n.e.c.					
– Firm 1 (office furniture)	240	27	32.999	50	0,5
– Firm 2 (other furniture products)	211	78	35.999	75	4,5
– Firm 3 (other furniture products)	104	7	13.800	84	2
– Firm 4 (broom)	48	50	5.880	2	1,3
– Firm 5 (other products)	62	11	13.800	5	0
– Firm 6 (other products)	154	24	12.000	10	0
Food products and beverages					
– Firm 1 (meat)	40	28	4.200	10	2
– Firm 2 (margarine)	70	49	18.000	30	1,5
– Firm 3 (bread)	250	10	12.000	0	0
– Firm 4 (wine)	100	82	25.499	5	0,15
Textiles and textiles products					
– Firm 1 (linen)	40	16	19.998	80	0,45
– Firm 2 (cotton)	110	19	16.800	75	0,96
– Firm 3 (finishing products)	154	30	12.000	0	0,1
– Firm 4 (other textile products)	40	25	7.200	40	1,8
– Firm 5 (other textile products)	180	113	11.982	35	2
– Firm 6 (knitted)	40	11	6.600	70	0,7
Wood, pulp, paper, paper products, printing and publishing					
– Firm 1 (stationery)	56	85	7.200	20	0
– Firm 2 (paper)	154	71	23.964	42	-
– Firm 3 (paper)	54	56	5.700	5	2,5

Appendix 5.A: Section of the EMS questionnaire regarding technologies

3 Which of the following technologies are currently used in your factory?

First use (year)[1]	Estimation of used potential[2]	YES	Technologies	NO	Use planned: in the course of the next 2 years	Use not planned, as: lack of a technological/ commercial solution	Use not planned, as: not applicable in the plant
19/20	%		Computer aided design (CAD)				
19/20	%		Virtual reality or simulation for product design				
19/20	%		Computer controlled machinery or equipment (CAM)				
19/20	%		Industrial robots and automated handling systems (for tools or parts)				
19/20	%		Computer controlled warehouses/ material handling systems				
19/20	%		Automated machine vision systems (e.g. for quality inspection, process management)				
19/20	%		Process integrated quality control (Inline, e.g. with laser, ultra sonic waves, sensors)				
19/20	%		cleanroom facilities (e.g. to manufacture electronic components, food, etc)				
19/20	%		Enterprise resource planning software				
19/20	%		Simulation of production process design				
19/20	%		Electronic procurement (Purchase from suppliers via internet)				
19/20	%		Supply chain management (Exchange of production schedule data with other companies)				
19/20			Bio- /genetechnological methodes or catalytic converters				