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1. Introduction

This paper aims to contribute to the analysis of within industry inter-firm variety. Building upon the knowledge-based theory of the firm (Nelson and Winter, 1982; Penrose, 1959; Fransman, 1994), this paper develops two themes. First, the analysis of intra-industry heterogeneity: why do firms that operate in the same industry differ, and why are such differences persistent? Second, the paper investigates the extent to which higher performance is associated with the capacity of firms to expand their knowledge base (rather than with their initial conditions).

Several authors (Patel and Pavitt, 1997, Granstrand et al., 1997) have pointed out that, even when large firms are increasingly technologically diversified, their technological competencies profiles are similar within industries while differing significantly between industries. At the same time, empirical evidence suggests that firms within the same industry display distinct strategic paths (Noda and Collis, 2001; McGee and Thomas, 1986). These two streams of empirical evidence have led to the argument that there is not a one-to-one match between technological competence and product specialisation and that the dynamics of technological diversification are different from the dynamics of downstream diversification (Gambardella and Torrisi, 1998). This paper aims to contribute to this discussion, providing concrete empirical evidence on how firms accumulate technological competencies and whether firms that manage to expand their knowledge bases are rewarded with indicators of better performance.

The main contribution of the paper is empirical, based on a data source consisting of information on documents published in scientific international journals by Spanish pharmaceutical firms. As McMillan and Hamilton (2000) pointed out, the pharmaceutical industry is particularly appropriate for the employment of bibliometrics given that scientific research is critical to the development of new drugs. The Spanish pharmaceutical industry provides the setting for the study as an industry behind the technological frontier, where different levels of commitment to technological catchingup processes by firms are possible. We examine the extent to which Spanish pharmaceutical firms are building capabilities in research, and about the kind of capabilities being built.

The paper is structured as follows. Section 2 reviews the literature and lays out the questions to be addressed. Section 3 describes the data sources. Section 4 identifies the two groups of firms we propose to analyse by describing their research and economic performance. Sections 5, 6 and 7 provide empirical evidence on different aspects of the knowledge accumulation process. Section 8 discusses the relationship between knowledge breadth and performance. Finally, Section 9 presents the conclusions.

2. Literature background

The purpose of this paper is to study the factors that shape the scope and direction of firm's technological capability accumulation and to examine the extent to which such factors are relevant drivers of persistent intra-industry heterogeneity. As stated by Cockburn et al. (2000), there is no generally accepted theory about the origins and dynamics of competitive advantage: some scholars stress the firm's external environmental conditions (Porter, 1980), others highlight the firm's endowments of valuable, rare and difficult-to-imitate resources (Barney, 1991). By conceptualising the firm as a learning organisation, focusing on the ability of the firm to develop new capabilities, the knowledge-based theory of the firm provides a distinctive and fruitful framework within which to analyse how firms rebuild the industry structure to their advantage. In this sense, the knowledge-based theory of the firm provides an avenue for articulating the complementarities, interconnections between Porter's external environments and Barney's firm specific endowments, on a dynamic basis.

2.1. Variety and stability of firms' knowledge bases

The knowledge-based theory of the firm aims to bring to the fore the argument that firm differences matter. Different perceptions and understanding of the economic environment may lead firms in the same line of business to employ different strategies. The strategic management literature has provided strong evidence of the variety of strategies operating among firms within similar industries (McGee and Thomas, 1986).

However, it is worth noting that when looking at the technological competencies accumulated by firms in the same industry, firms tend to display substantially similar profiles. Patel and Pavitt (1997) show that firms' technological profiles (as measured by the distribution of patents across technical fields) are similar within industries while differing significantly between industries. In other words, firms competing in the same industry tend to accumulate similar technological competencies.

This paper argues that the two above mentioned features are not in conflict: while firms need to accumulate a similar set of technological competencies to compete in a certain industry, firms are likely to 'use' such competencies in different ways. Or, in other words, the firm's knowledge base consists of something more than the distribution of patents (or publications) across technological fields; it also embraces how firms deploy such competencies to deliver new products. As Pavitt (1998) and Nelson (1998) argue, there are two complementary elements in firm-specific knowledge: bodies of understanding (based on competencies in specific technological fields) and bodies of practice (which refers to the organisational knowledge that links the bodies of understanding with the firm's downstream, product specialisation). Dibiaggio and Nesta (2003) recently expanded this discussion by examining the empirical foundations of these two concepts (studying the changing nature of the firms' knowledge base in the context of biotech-related industries). Building upon the distinction between bodies of understanding and bodies of practice, this paper argues that intra-industry firm diversity should be analysed appropriately not only by examining the firms' technological competencies (bodies of understanding) or the firms' product diversification strategies, but also by paying attention to the interface between the two. In this paper, we study this 'interface' by focusing on the firms' research activities examined according to the products or processes that such activities are expected (by the firms) to originate and develop.[1] From hereon, we refer to this 'interface' as downstream-profiled research activities. However inappropriate this terminology may be (and we admit that it is not very satisfactory), we do not conceive downstream-profiled research activities as being equivalent to applied research; on the contrary, we mean by this term to embrace

[1] Note that by focusing on the dowstream profile of the research activities we are only considering a small portion of what Pavitt (1998) and Nelson (1998) meant by 'bodies of practice'. The downstream profile of research activites is just one of the many components of the firm's organizational knowledge. Nevertheless, it is, we argue in this paper, a crucial component.

research activities that are very exploratory in nature, so long as the exploration is conducted with a goal (expected materialisation) in mind.

Moreover, as has been stressed by many authors (Stiglitz, 1987; Pavitt, 1987; Cantwell, 1989; Antonelli, 1999), the process of firms' learning is characterised by being a local process of knowledge acquisition: firms do not appear to scan all possible choices, but rather 'they follow a specific course acting almost instinctively to capitalise on their past experience' (Holbrook et al., 2000: 1030). In this sense, the evolution of firm's knowledge base profiles over time can be characterised as being cumulative and incremental and, thus, can be predicted to display a fairly stable pattern over time.

In short, building upon the above discussion, we hypothesise that firms display stable patterns of specialisation (or diversification) in downstream-profiled research activities (that is, research activities evaluated according to the products or processes that they are expected to enable), and that such stable patterns of specialisation vary widely across firms.

2.2. Knowledge strategies and performance

As several authors (Henderson and Cockburn, 1994; Powell et al, 1996) have noted, superior performance is associated with the firm's capacity to create and accumulate knowledge - from the stock of patents in specific disciplines to research network particularities and other forms of organisational architectures devoted to learning processes. In this sense, the management of knowledge becomes a crucial dimension for developing valuable, rare, difficult-to-imitate and non-substitutable resources: in other words, a source of competitive advantage (Leonard-Barton, 1995; Bierly and Chakrabarti, 1996).

A degree of consensus has emerged among scholars as to what constitutes the crucial conflicting (but potentially reinforcing) forces that knowledge management needs to reconcile or balance in order to create an active and fruitful learning organisation (Argyris and Schön, 1978; Leonard-Barton, 1995). First, as argued by Cohen and Levinthal (1989, 1990), March (1991) and Levinthal and March (1993), firms are likely to be rewarded in the long term with greater knowledge creation capabilities (and also with long term survival) the more they invest in in-house search activities and the more exploratory the nature of the search, since such efforts contribute to strengthening the firm's capacity to take advantage of knowledge generated outside its boundaries, and counterbalance the myopic features of experiential learning. However, such strategies generally involve higher levels of risk and costs than strategies guided by short-term optimisation of resources.

Second, firms need not only to be competitive specialised players - in order to achieve world-class command within a certain discipline - but they also need to broaden their areas of expertise. This is so because broadening the knowledge base helps the firm, on the one hand, to be flexible in the face of technological change and on the other hand, to impose causal ambiguity on competitors by creating knowledge through the combination of different (but familiar to the firm) technologies or bodies of understanding (Leonard-Barton, 1995; Brusoni et al., 2001). However, as Pavitt (1998: 440) points out, it is diversity downstream (in the product and process configurations that can be generated from a given technological knowledge) rather than just technological diversity (which tends to be similar among firms within industries) that drives competition amongst innovating firms.

Building upon the above discussion, we would expect that better performance is strongly associated with the firm's capacity to expand the scope of its areas of expertise in research activities. We also examine whether the firms' diversity in technological competencies and firms' diversity in downstream-profiled research activities impact differently on performance.

3. Description of data sources and variables

This research addresses the implications for empirical analysis of the propositions, discussed in Section 2, drawing upon the knowledge-based theory of the firm. Our empirical analysis is designed to throw light on the characteristics of firms' knowledge bases and on their implications for firms' competitive positions and innovative capabilities. To do this, we focus on the publication profiles of a set of active research players in an R&D intensive industry: the pharmaceutical industry. Publication counts are an important indicator of research activity in the pharmaceutical industry, as shown by Koenig (1983), Narin and Rozek (1988), Gambardella (1995) and McMillan and Hamilton (2000) among others. Also, as noted by Cockburn et al. (2000), firms at the technological frontier have increasingly adopted a 'science-driven drug discovery' process: that is, firms not only tend to publish on average more over time, but they also tend to converge towards similar levels of publishing.

The main objective in constructing the sample of pharmaceutical firms was to include every Spanish domestic firm active in research in order to have a sample of firms with a similar strategy. In other words, the aim was to work with an innovative group of firms seeking to accumulate capabilities oriented towards the generation and development of new products.

We considered every domestic firm that had published at least one document in the period 1981-2000. The publication data were gathered from the Institute for Scientific Information's (ISI) Science Citation Index (SCI) and the Web of Science. We collected data about every document published in the journals included in the ISI SCI in this period for which at least one author address was that of a Spanish domestic pharmaceutical firm.

This yielded a total of 1,210 published documents and a sample of 32 pharmaceutical firms (the list of firms is included in the Appendix) – accounting for approximately 28% of the total Spanish pharmaceutical market in 1999 in terms of sales. Most of these firms were founded before 1955, and to a large extent they have continued to be domestic-owned since then; however, 11 out of the 32 firms had undergone changes in their ownership structure due to partial or total acquisition by multinational corporations (MNCs). Since most of these acquisitions only occurred in the eighties and nineties, and since author affiliations in all cases included domestic addresses, we included all 32 firms in our research.[2]

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[2] Moreover, from a random sample of 50 single authored articles (published since 1998), we confirmed that, with the exception of three cases, the authors were effectively affiliated to the firm (and not to a university or other publicly funded research centre). Therefore, we are confident about our assumption that authors are effectively affiliated to the firm. We are grateful to Dr F.Jimenez-Saez (INGENIO, Universidad Politecnica de Valencia, Spain) for his assistance in identifying authors' affiliations.

We draw on publication data to build distinct measures capturing the different features of the firms' knowledge base that we aim to study. First, to study trends in the firms' in-house research efforts we calculate the ratio of publications counts relative to firm size (in terms of total employees) on an annual basis. Second, to study the exploratory nature of the research we employ the concept of ''research level'' developed by CHI in order to classify journals on a continuum from the most applied to the most basic scientific research. As Narin and Rozek (1988) noted, in the context of biomedicine the four types of research are: clinical observation (Level 1), a mix of clinical observation and clinical investigation (Level 2), clinical investigation (Level 3) and basic research (Level 4).[3] Given that most of the journals in the SCI database have been assigned to one of these levels, we can calculate the average research level for the publications of a given firm at any point in time. Finally, the profiles of firms' knowledge bases are defined in terms of both the distribution of publications across scientific sub-fields and the therapeutic categories to which each publication belongs (see Sections 7 and 8 below). Sales data come from IMS Spain publications, employment and performance data are from Dun & Bradstreet and Sistema de Analisis de Balances Ibericos (SABI) publications.

4. The Spanish pharmaceutical industry: research and economic performance of Spanish pharmaceutical firms

4.1. The regulatory environment

We focus on the Spanish pharmaceutical industry to test the propositions derived from the knowledge-based theory of the firm. One of the interesting features of this industry case is that the regulatory environment has not been characterised historically by specific strategies oriented towards innovation. In fact, long-term survival in the industry has not depended on research commitments for two main reasons. First, the lack of product patent protection until 1992 (Sequeira, 1998) and, thus, the existence of a regulatory environment that did not penalise imitation. Second, the Spanish national health system's lax regulatory criteria for product introduction has favoured horizontal product differentiation strategies and, thus, lowered industry entry barriers (Lobo,

[3] As Narin and Rozek (1988) state, Level 1 is typified by the *Journal of the American Medical Association*, Level 2, by the *New England Journal of Medicine*, Level 3, by the *Journal of Clinical Investigation* and Level 4, by the *Journal of Biological Chemistry*.

1992). Therefore, this study is examining the innovative patterns of a group of small and medium sized firms (SMEs) that have been faced with a less than encouraging innovation environment and which have followed a strategy mainly driven by purposive efforts towards rebuilding the industry structure in their favour.

Indeed, as is shown in Section 4.3, a small set of Spanish domestic firms has been able to introduce world-class innovations (measured by new chemical compounds patented internationally). The focus of this research on firms that are reported to conduct research activities, allows us to investigate the extent to which research active players display similar or different knowledge management strategies. Firms that have relied exclusively on other sets of capabilities (i.e. marketing and/or manufacturing) in order to survive in the industry are not considered.[4]

In this context, we wonder whether the knowledge base developed by the firms that have managed to obtain international patents (i.e. have innovated at world-class levels) is significantly different from those of other Spanish domestic firms conducting research activities.

4.2. Research activity as captured by publications

As mentioned above, Spanish domestic firms published 1,210 documents between 1981 and 2000, 1,032 of which were citable (all type of documents excluding Meeting Abstracts).[5] It is clear from the evidence provided here that Spanish pharmaceutical firms publish much more than they patent. Comparing the number of documents published by Spanish domestic pharmaceutical firms and the number of patents granted to Spanish domestic pharmaceutical firms by the US Patent Office (USPTO) in the

[4] Also, in order to have better control of the origins of the accmulated technological knowledge, we studied only domestic companies to ensure that the research capabilities studied were effectively taking place in the firms analysed and not in foreign parent companies.

[5] This research provides evidence supporting the argument that the use of publications can be a good alternative to patents to address the innovative activities of firms in behind the technological frontier industries. In such industries firms have generally failed to achieve a critical mass of patents sufficient to allow for robust measures of innovative activities. Nevertheless, a caveat must be applied to the use of publications that the methodology may be applicable only to a very restricted group of industries, and particularly those generally classified as R&D intensive, where firms are forced to be well connected to the open science community in order to keep abreast with crucial technological advances.

period 1981-2000, publications clearly dominate (see Figure 1).[6] Moreover, not only is the number of publications always higher than the number of patents, but also the trend is towards continued increase. While the annual average number of documents published by Spanish domestic firms was 27 between 1981 and 1984, this rose to 108 in the period 1997-2000.

{Insert Figure 1 about here}

This increasing number of published documents is not just the product of an increasing number of firms publishing, or the result of less high quality research. Firms' research efforts (as measured by number of publications per firm size), and the scientific value of these publications (as measured by the number of citations per document) have not been negligible. When compared to pharmaceutical firms at the technological frontier, Spanish firms display close to average levels of citations per paper and levels of research efforts. Table 1 provides figures comparing a group of US pharmaceutical firms with some of the Spanish firms most actively publishing. It can be seen that generally the two groups of firms are similar in most respects except the scale of publications. In other words, according to the publications data, there is a set of Spanish domestic firms that perform relatively well in terms of quality of research and research productivity, when compared with firms at the frontier.

{*Insert Table 1 about here*}

4.3. Successful vs. 'unsuccessful' innovators

While a relatively large number of firms have been active in research, as shown by the publications data, not all firms that publish have been equally successful in terms of technological performance (i.e. achieving international patents from active ingredients developed in-house). Indeed, only five firms can claim to have been successful in introducing new in-house chemical entities for which international patents have been granted and for which licences granted to MNCs. Table 2 summarises the group of Spanish firms that have successfully commercialised new products based on in-house

[6] Patent data were gathered from the USPTO, the patents selected being those in which patent assignees were Spanish domestic firms, within the category 'Drug, bio-affecting and body treating compositions' (Class Numbers 424 and 514) from the US Patent Classification.

developed active ingredients. It should be noted that a large proportion of these in-house developed, internationally patented products have been economic successes, accounting for over 10% of total sales within a few years of market introduction (Galdon, 1996; D'Este, 2003).[7]

We will refer to this group of firms as 'innovative firms', as opposed to the other firms that publish but that have not been successful in developing in-house active ingredients, which we will refer to as 'non (successful) innovative' firms. This designation does not mean that this group of firms is not undertaking innovative activities; on the contrary, this latter group has obtained a large number of international patents over the period 1981-2000, but for new methods, processes or formulations rather than new active ingredients. The innovative firms group comprises five firms; the non (successful) innovative group accounts for the other 27 active research firms (as shown by their publication counts).

{*Insert Table 2 about here*}

4.4. Economic performance

Regarding economic performance, there are two issues to be noted. First, the group of innovative firms has been continuously growing since the mid-sixties, while the non-innovative group has seen a persistent decrease in its aggregate market share (see Figure 2). Furthermore, the increasing market share of the innovative firms is even more striking when compared with the sharp decrease in the portion of the total market absorbed by all the other domestic firms. Second, the case of the innovative firms would seem to indicate that firm size is not a sufficient condition for success in innovating. None of the innovative firms were among the largest domestic firms in 1965. Indeed, in 1965 Almirall was ranked 23rd in terms of sales including both domestic and foreign firms operating in Spain, with Esteve ranked 47th, Faes 20th, Ferrer 38th and Uriach 37th; while 6 domestic firms were among the largest 20 in the Spanish market by 1965 (most of them belonging to our group of non-innovators). Also, Almirall, Esteve and Uriach had begun research activities by the mid to late sixties - as stated in their company reports and confirmed by the fact that a large number of patents were granted

[7] This is a significant percentage of firm's total sales if we take into account that, as Schwartzman (1976) notes, the large majority of firms' most important products account for between 15% and 20%.

to these firms in the seventies (see Table 2). In other words, while the five innovative firms rank among the largest domestic firms in the eighties and nineties, this was not the case in the mid sixties, and innovative success seem to have been either a causal factor of, or occurred simultaneously with, the process of growth experienced by these firms.

{*Insert Figure 2 about here*}

5. Basic trends in research efforts

In this section we study the temporal profile of firms' research activities and research efforts using the information on counts of published documents. As argued in Section 2, we would expect that a firm's innovative success would be related to the firm's in-house research efforts. Thus, it would be expected that the intensity of the research efforts of the group of innovative firms would be higher over time.

When we compare firms' research intensity over time (see Figure 3), the picture that comes out is that innovative firms, when comparing the 5 year moving averages, have higher levels of publications per hundred employees. However, these levels are only significant for five years when comparing the raw data on an annual basis.

{*Insert Figure 3 about here*}

Besides research intensity, it is also important to investigate whether these firms have been increasingly moving towards a higher degree of basic research activities: moving from clinical observation towards clinical investigation and basic research. In accordance with the discussion in Section 2, we would expect that those firms that have been able to innovate – that is, to create new molecules - should show an increasing capability to command basic research. We examine this by classifying each publication in terms of type of research using the CHI research typology described in section 3, which classifies each document according to the type of journal in which it was published. The four categories of research are: clinical observation (Level 1), a mix of clinical observation and clinical investigation (Level 2), clinical investigation (Level 3) and basic research (Level 4).

In analysing the distribution of publications over time across the different types of research, the non-innovative firms show an increasing proportion of publications in clinical observation (Levels 1 and 2) type of research, while the group of innovative firms is shown to have increased (by 10 percentage points) the proportion of publications in basic research (see Table 3).[8]

Thus, the innovative firms not only increased research intensity over the period 1981-2000 (as shown in section 6.1) more than the non-innovative firms, but also it increased the proportion of publications in basic research (see Table 2), indicating that these firms had research capabilities that allowed them to conduct research of a more exploratory nature.

{*Insert Table 3 about here*}

6. The breadth of firms' knowledge bases

As discussed in Section 2, in order to achieve world-class command within a certain discipline, firms need not only to be competitive specialised players, but they also need to broaden their knowledge base (Leonard-Barton, 1995; Patel and Pavitt, 1997; Brusoni et al., 2001). In this section we investigate whether firms have been broadening their knowledge base by studying two different dimensions of knowledge expertise. We look at the scope of the scientific bodies of knowledge that firms have managed to integrate, as captured by the number of scientific disciplines in which firms have published. This can be interpreted as the firm's scientific competencies (for similar interpretation and methodology for the pharmaceutical industry, see Narin and Rozek (1988)). We also investigate whether firms have expanded their knowledge expertise in terms of product-oriented research activities. Firms that are active in research in the pharmaceutical industry are oriented towards the discovery and development of products that claim to be therapeutically novel. To achieve this goal, firms need to accumulate a certain level of experience in order to be effective in researching in a given therapeutic area (Henderson and Cockburn, 1994). Therefore, we look at the

[8] It should be noted that the increasing proportion of documents classified in the category of clinical investigation is due to a large extent to the weight of three firms publishing extensively in scientific fields (i.e. allergy) in which clinical observation plays a disproportionate role.

scope of firms' publications across therapeutic areas. We wonder whether there is a tendency for firms to be relatively specialised around a narrow set of therapeutic fields and also wonder about the stability of their specialisation. We also investigate the extent to which firms have managed to diversify their research portfolio across therapeutic areas and their capacity to conduct research on products intended to be active agents against various diseases.

6.1. Examining the firms' knowledge base: diversification of scientific competencies

This section, then, looks at whether firms have managed to integrate knowledge across a wide variety of scientific fields or have been accumulating scientific knowledge in only a narrow set of scientific fields. The CHI classification of journals in scientific fields (and sub-fields) is used in order to calculate the extent of diversification across scientific fields of firms' published documents. It can be seen that 99% of the documents published by the Spanish pharmaceutical firms belong to three aggregate scientific categories: Clinical Medicine (including scientific sub-fields such as Pharmacology, Pharmacy, Cancer, Cardiovascular System, Gastroenterology, etc.), Biomedical Research (including sub-fields such as Biochemistry & Molecular Biology, Microbiology, Biomedical Engineering, etc.) and Chemistry (i.e. Organic Chemistry, Analytical Chemistry, Physical Chemistry, etc.). This distribution profile of publications is essentially the same as that described by Narin and Rozek (1988) for the US pharmaceutical industry in 1976, where 86% of firms' publications were classified in these three aggregated scientific categories (although the firms were much more diversified in terms of scientific sub-fields than those studied here). This similarity in the scope of scientific fields points to the fact that firms in the same industry need to accumulate similar ''background'' knowledge in order to become active research players (Patel and Pavitt, 1997).

In order to compare the scientific knowledge diversification of innovators and non-innovators in a meaningful way, we need to establish a minimum number of publications (some firms have too few to infer anything in terms of diversification). To do this, we compare the group of innovative firms with a sub-sample of 14 firms from the non-innovative group, which published at least 10 documents during 1981-2000.

These two groups differ significantly in terms of size (number of employees), the group of non-innovative firms having an average size of 420 employees and the innovative firms 1,000 employees.[9]

Table 4 summarises the degree of diversification of documents published across scientific sub-fields by Spanish pharmaceutical firms in the period 1981-2000. It can be seen that the two groups of firms have very similar levels of diversification, either as measured by the Herfindahl Index (1 minus Herfindahl Index, to have a measure of diversification instead of concentration) or as measured by the percentage of publications in the most important scientific sub-fields. Moreover, even when the number of scientific sub-fields in which the firm has published at least one document is two times higher in the innovative group, the publication ratios of two groups do not significantly differ when the number of publications is normalised by the number of employees.

{*Insert Table 4 about here*}

According to Table 4, we would reject the hypothesis that innovative and non-innovative firms display different diversification levels of scientific competencies. Both types of firms have accumulated scientific expertise along a similar number of fields. There is no sign that innovative firms present a pattern of publications more evenly distributed across scientific fields, nor that they are actively publishing across a larger number of scientific fields (relative to their size). Moreover, consistent with Patel and Pavitt's (1997) findings, our data show that firms competing in the same industry display similar knowledge base profiles. As will be shown in Section 7, the firms studied here have a distribution of publications across a similar spectrum of scientific sub-fields.

6.2. Examining the firm's knowledge base: diversification of downstream-profiled research activities

[9] These 14 firms are: Abello, Alter, Andromaco, Antibioticos, Cusi, Lacer, Lasa, Menarini-Puig, Vinas, Vita, ASAC, Leti, Grifols and Salvat. The average number of employees in these 14 firms at the end of

In this section we investigate whether firms have managed to diversify their knowledge base across therapeutic areas (i.e. cardiovascular system, respiratory system, etc.). As in the examination of scientific fields, we investigate whether firms have been able to accumulate knowledge across a wide variety of therapeutic scientific fields or have accumulated knowledge in only a narrow set of therapeutic areas. To do this we classified the publications in terms of therapeutic fields (across the 15 therapeutic fields at the 1 digit level of the Anatomical Therapeutic Classification (ATC)).[10] The classification was carried out on the basis of the information contained in the keywords and abstracts provided by the ISI SCI database. Of the 1,032 citable documents (all documents excluding Meeting Abstracts), 12.8% were not classifiable into a therapeutic category because no clear indication could be obtained from the keywords or abstracts. In most cases, the papers that were not classified belonged to basic research (Level 4 of CHI research typology), which explains why no particular therapeutic area was indicated. This could be due to the exploratory nature of basic research and/or because the documents focused on the chemical characteristics of the molecule (rather than on its potential therapeutic effects).

Table 5 provides figures on the diversification of firms' publications across therapeutic categories comparing, as we did in Table 4, the firms in the innovative group with the 14 largest firms from the non-innovative group. The patterns this time are significantly different. Innovative firms display a much higher degree of publication diversification across therapeutic fields.

{*Insert Table 5 about here*}

If we look at the profile of publications across therapeutic fields for these two groups of firms, it can be seen that the innovative firms display a broader spectrum of research expertise, while non-innovators remain narrowly focused throughout the period considered (1981-2000) (in several cases one therapeutic area accounts for all the documents published by the firm).

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the nineties ranged between 80 and 1,900, while the average size for the five innovative firms was between 600 and 1,800.

[10] The 15 therapeutic areas are: Alimentary Tract and Metabolism (A), Blood and Blood Forming Organs (B), Cardiovascular System (C), Dermatologicals (D), Genito-Urinary System (G), Systemic Hormonal Preparations (H), General Anti-Inefctives (J), Cytostatics (L), Musculo-Skeletal System (M), Central

To sum up, analyses of the firms' knowledge base diversification in terms of scientific knowledge background and in terms of research pipeline produced very different results. While both groups display a similar degree of diversification across scientific fields, they significantly differ in the degree of diversification of their research across therapeutic areas. Innovative firms have achieved a much broader knowledge base in terms of research across therapeutic fields than non-innovative firms.

7. Variety and persistence of the firms' knowledge base

So, we can study the knowledge base of firms by looking at two different dimensions: the extent to which the firm has been able to expand its knowledge across scientific fields in order to conduct research activities and the extent to which the firm has been able to expand its research portfolio across therapeutic areas. In this section we focus not on the extent of diversification, but on the diversification profile in order to analyse both distinctiveness and stability of the knowledge base.

It has been shown that firms' scientific knowledge bases are similarly diversified between innovative and non-innovative firms. We now want to test whether the composition of scientific fields in which firms are accumulating knowledge is similar or different across firms. In order to answer this question, we correlated each firm's scientific knowledge profile (i.e. publication shares across scientific sub-fields) against those of all other firms . We consider all scientific sub-fields in which firms publish at least once over the period 1981-2000: this produces a total of 38 scientific sub-fields, 84% corresponding to Clinical Medicine and Biomedical Research and 11% to Chemistry related sub-fields (the remaining 5% corresponding to Biology and Agriculture & Food Science).[11] We find that the scientific knowledge profiles of these

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Nervous System (N), Parasitology (P), Respiratory System (R), Sensory Organs (S), Diagnostic Agents (T) and Various (V).

[11] The 38 scientific sub-fields are: General & Internal Medicine; Allergy; Cancer; Cardiovascular System; Dermatology; Endocrinology; Gastroenterology; Geriatrics; Hematology; Immunology; Obstetrics-&-Gynecology; Neurology & Neurosurgery; Ophthalmology; Arthritis & Rheumatology; Pathology; Pharmacology; Pharmacy; Respiratory System; Nephrology; Veterinary; Hygiene & Public Health; Misc. Clinical Medicine;Physiology; Embryology; Genetics & Hereditary; Biochemistry & Molecular Biology; Cell Biology, Cytology, Histology; Microbiology; Virology; Biomedical Engineering; Microscopy;

firms are remarkably similar, as indicated by the fact that 53% of the cross-firm correlations (90 out of 171) were positive and significant (see Pearson correlation coefficients in Table 6).[12] This evidence confirms that there are strong similarities in the scientific knowledge profile accumulated by firms in the same industry, regardless of whether or not they are successful innovators.

{*Insert Table 6 about here*}

These results are consistent with those of Patel and Pavitt (1997), which show that profiles of patent shares are more likely to be similar among firms belonging to the same industry than among firms belonging to different industries. However, here we are not comparing the firms' knowledge profiles with those of non-pharmaceutical firms, but we provide a much more detailed disaggregation of the composition of firms' knowledge profiles. In other words, the evidence here highlights that firms accumulate knowledge in similar scientific sub-fields (mainly within biomedicine) and firms have similar knowledge base composition in terms of the profile of scientific sub-fields in which they publish. This evidence points to the fact that pharmaceutical firms need to accumulate a similar scientific knowledge background in order to become active research players; or in other words, diversity in technological (or scientific) competencies can be interpreted as an entry barrier to competition in innovation.

A completely different picture emerges when we address the firms' research portfolio in terms of the distribution of publications across therapeutic areas. We correlate each firm's publication shares across therapeutic areas against the other firms, based on the group of five innovative firms and the top 14 from the non-innovative group. We consider all therapeutic areas (at the 1 digit level of the ATC) in which at least one document has been published by any of these firms in the period 1981-2000, which is all 15 categories. As Table 7 shows, each firm displays a distinct research portfolio. More than 86% of total possible correlations between firms were not significantly different from zero (at the 5% level of significance, using either Spearman or Pearson

General Biomedical Research; Organic Chemistry; Analytical Chemistry; Physical Chemistry; General Chemistry; Biology; and Others.

[12] When Spearman rank-order correlation coefficients were used, 48% of correlations were positive and significant: see table in appendix.

correlation coefficients).[13] Therefore, the knowledge base varies to a large extent across firms in terms of their knowledge accumulation in research across therapeutic areas. In other words, variety across firms is largely confirmed by the firms' research portfolios and thus supports the proposition that learning (knowledge creation) is a firm-specific, localised process. Firms deploy a common (though industry specific) set of scientific competencies along a variety of firm-specific research paths oriented to the generation and development of new products.

{*Insert Table 7 about here*}

Finally, we investigate whether the firm's knowledge base is stable over time in order to assess the extent to which learning processes build upon prior experience and the extent to which the localised nature of learning imposes restrictions on shifts towards new, previously unexplored areas. Given that most of the non-innovative firms published in the nineties but not in the eighties, and given that they present a very narrow pattern of research diversification across therapeutic fields, we focus on the group of innovative firms in order to study firm's knowledge base stability (see Table 8).

We test whether stability in firms' knowledge base is a significant phenomenon using the results derived from the correlations between the distributions of publications across therapeutic areas in different periods of time for each of the five innovative firms. The results, shown in Table 8, reject in all cases that the distribution of publications over time (for each firm) is random, highlighting that firms' research across therapeutic areas does not change abruptly over time, which supports the proposition that cumulativeness is a major influence on firm's research choices.

{*Insert Table 8 about here*}

8. Knowledge base diversification and performance

We conducted some regressions to examine the relationship between company performance and knowledge base diversification. The sample is composed of 19 Spanish pharmaceutical firms (the five innovative and 14 most active non-innovative)

[13] Spearman rank-order correlation coefficients are shown in the appendix.

during the period 1995-2000. Three measures of performance were applied: (1) returns on sales (ROS); (2) returns on assets (ROA); and (3) the log of sales per employee (LN(SALES/L)).[14] We regressed each of these measures on three sets of variables. First, a set of variables accounting for the extent to which the companies expanded their knowledge base, both in terms of scope of technological (scientific) competencies and in terms of scope of downstream-profiled research activities, during the period 1995-2000. Second, a set of variables accounting for the '''initial''' conditions of the company: age and size at the beginning of the period (1995). And third, a set of two variables accounting for firms' investment efforts in physical assets (the stock of capital over employees during the period 1995-2000) and number of employees over the period 1995-2000.

To measure the first set of variables we have used the used the Herfindhal Index: more precisely, we have computed '1 – Herfindhal Index' in order to have a measure of diversification on a year by year basis, over the firm's distribution of publications, both across scientific fields and across therapeutic areas. Thus, we define $THERAPSCOPE_{it}$ as the '1-Herfindhal index' computed on each firm's distribution of publications across therapeutic categories for every year during 1995-2000. $SCIENCESCOPE_{it}$ is the '1 – Herfindhal index' of the distribution of publications across scientific fields computed for every year and every company.[15] These two variables measure the extent to which the companies have expanded their knowledge base over the period 1995-2000. We use subscript 'i' to denote firms and 't' to denote time.

We also include a set of variables to assess the extent to which the firm displayed a highly diversified (or narrow) knowledge base at the beginning of the period considered. First, we computed the degree of knowledge diversification (1-Herfindhal index) for each firm, on the basis of its distribution of publications over the period 1981-1994. This was done for both the distribution of publications across therapeutic areas ($THSCOPE95_i$) and across scientific fields ($SCISCOPE95_i$). We also explored another

[14] Sales figures, after-tax profits and value of total assets were obtained from CD ROM SABI – see www.informasa.es.

[15] Note that for each single firm (and year) we have used data on firms' publications for the four preceding years, and then calculated a five year average. Therefore, the distribution of publications corresponding to the year 1995 includes both data on publications in that year and also data on firms' publications in the four preceding years. This is done in order to make the best use of the information available and to obtain more meaningful trends for these variables.

way to capture the firm's 'accumulated' knowledge breadth: an alternative regression includes $LN(STOCKPUB)_i$, which accounts for the total amount of papers published by the firm between 1981 and 1994, and two interaction variables that assess the 'combined' effect of the firm's stock of publications with $THSCOPE95_i$ (called $INTERACT1_i$) and with $SCISCOPE95_i$ (called $INTERACT2_i$).

The second set of variables attempts to control for the firm's conditions pre-1995. In particular, we consider the firm's size in 1995 (in terms of the log of number of employees, $LN(EMP95)_i$), and the age of the firm (AGE_i) to assess whether firm size and earlier entry have a positive impact on performance. A positive impact of these two variables could be expected because of the greater internal financial resources available to larger firms and as a result of first-mover advantages gained by early entrants.

Finally, we also want to assess whether the firm's commitment to investments in physical assets is strongly associated with performance, compared with the firm's efforts towards intangible assets (such as those that are accounted for by $THERAPSCOPE_{it}$ and $SCIENCESCOPE_{it}$). We take the stock of capital per employee, as capturing the firm's capital intensity deepening ($LN(K/L)_{it}$),[16] and the firm's number of employees over time ($LN(EMP)_{it}$).[17]

Thus, using a linear specification, our regressions are of the following form (where the dependent variable is one of our three measures of performance):

$$PERFORMANCE_{it} = CONST + \beta_1 THERAPSCOPE_{it} + \beta_2 SCIENCESCOPE_{it} + \beta_3 (LN(EMP95))_i + \beta_4 AGE_i + \beta_5 THSCOPE95_i + \beta_6 SCISCOPE95_i + \beta_7 LN(K/L)_{it} + \beta_8 LN(EMP)_{it} + \varepsilon_{it}$$ [18]

[16] Stock of capital is measured by the firm's value of annual 'total assets' , obtained from SABI.
[17] With the exception of variables accounting for firms' knowledge diversification, all other variables have been computed using 3 year moving averages. So, for example, the values for firm employees in 1995 is the average of the number of employees for the years 1994, 1995 and 1996.The same procedure was followed for the three performance measures.
[18] This is the expression for our first specification. The second specification includes the stock of publications and the two interaction effects (while removing the two variables accounting for the accumulated degree of firm's knowledge base diversification up to 1995).

Table 9 presents the OLS estimates. One of the interesting outcomes displayed in Table 9 is that the estimated coefficient of THERAPSCOPE is positive and significant in all regressions. This shows that there is a positive relationship between all performance measures and the extent to which firms have expanded their downstream-profiled research activities. Also, such positive relationship is not outweighed by the impact of firm size or firm's capital intensity deepening and, thus, the strength of the relationship between THERAPSCOPE and performance has proved to be robust.

The other measure of firm's knowledge breadth – the extent to which the firm has expanded its scientific competencies – is more erratic in terms of its degree of association with performance. However, in terms of the two measures of profit ratios, the diversification of accumulated scientific competencies is shown by the interaction effect (INTERACT 2) to have a positive impact on performance. In other words, it is not just the actual stock of publications that matters; whether this stock of publications embraces more scientific fields is also significant. In fact, these results indicate that firms that have accumulated scientific competencies in only a very narrow set of fields have been penalised in terms of performance (see the negative sign of the estimated coefficient for the variable LN(STOCKPUB)). These results are consistent with those from other studies (e.g. Gambardella and Torrisi, 1998) that show that better performance is associated with companies that have increased their technological diversification.

{*Insert Table 9 about here*}

One possible reason why the two variables accounting for firms' knowledge breadth display a different profile when related to performance may be due to time-lag features. The outcomes from the regressions in Table 9 provide some preliminary evidence to support the argument that the extent to which firms have managed to expand their scientific competencies has a positive, but deferred, impact on performance in comparison with firm's capacity to expand its downstream-profiled research activities (which seem to have a more direct, concurrent) relationship with performance). In other words, the opportunities arising from technological (or scientific) diversification may take a long time to materialise and, therefore, the impact of technological diversification on performance can be assessed better by focusing on firms' cumulative efforts.

There is one instance where firm scientific diversification (either accumulated or contemporaneous) is not significantly associated with performance. This is the case when performance is measured in terms of the log of sales per employees when the firm's capital intensity deepening may outweigh the long-term impact of variables related to technological diversification. Nevertheless, even in this specification, there is a significant and positive association between the firm's increasing diversification in downward-profiled research activities and performance.

Finally, it is important to note that such variables as initial size or age have very little or no impact on performance. This lends further support to the argument that purposive management (and particularly management of firms' intangible assets) is important in explaining performance: better performance does not emerge straightforwardly from earlier entry or larger size: deliberate efforts towards innovation must be made.Also, the fact that the estimated coefficient linked to the firms' efforts towards physical investments (stock of capital per employees) always shows a highly significant and positive association with performance, indicating that commitments towards accumulation of physical assets and broadening knowledge are complementary rather than substitutive. In other words, commitments in these two directions may be self reinforcing when assessed in terms of impact on innovative capacity and performance.

9. Summary and conclusions

There have been two themes running through this paper: intra-industry firm variety, and the relationship between the knowledge base and performance of the firm. The empirical results from this study support the following conclusions:

1. To get a better understanding of the interfaces between firms' technological competencies and product diversification, particular attention should be paid to downstream-profiled research activities. As the empirical evidence presented here shows, while firms competing in the same industry tend to accumulate competencies across a similar set of scientific fields, they display significantly different patterns in terms of the downstream (or product-

oriented) profile of research activities (here downstream-profiled research activities were studied by examining the distribution profile of publications across therapeutic areas).

Moreover, these differences persist over time: firms do not suddenly change their direction of research, but remain firmly committed to certain research paths, with gradual changes occurring over time. In short, both *variety* between firms and *persistency* in firms' differences within an industry owe much to the distinction between 'products' and 'technologies', and to the firm-specific organisational knowledge that allows a given set of technologies to be deployed in different ways.

2. Better performance is positively associated with the capacity of firms to expand their knowledge breadth, as measured both in terms of diversification of technological competencies and diversification of downstream-profiled research activities. However, the (positive) association with performance is much more consistent across different performance measures in the case of diversification of downstream-profiled research activities than in the case of diversification of scientific competencies (as measured by the degree of diversification of publications across scientific fields). This result is consistent with the argument in this paper that while technological competencies are essentially the necessary ticket of entry to competition in industry, it is how those technological competencies are organised to produce new products and processes that will potentially generate a distinctive capability and, eventually, may result in sustainable competitive advantage.

In summary, the empirical results support the argument that the firm's knowledge base is a main driver of persistent heterogeneity within industries on the one hand, because of the systematic variety in terms of how firms articulate and organise their research activities and their background knowledge, and on the other hand, because of the positive correlation between the firms' knowledge diversification and performance.

The fact that an industry behind the technological frontier was chosen for this analysis adds an additional dimension. This research provides evidence on the knowledge accumulation processes of technological followers in an R&D intensive industry. The extent to which these firms will be able to catch-up technologically with those at the frontier remains to be seen, but the evidence provided in this research shows that some firms have performed very well in terms of generating world-class innovations and acquiring research capabilities. The evidence shows that the successful innovative firms have been strongly committed to research activities for a long period of time and that these research activities are becoming increasingly explorative. Moreover, successful innovative firms have broadened their knowledge base (as measured by the accumulation of knowledge across therapeutic areas) to a greater extent than the (unsuccessful) innovative firms. Lastly, the evidence presented here shows that the deliberate, purposive efforts towards R&D investment are the basis of a virtuous circle - the relationship between market success and innovation.

This study has two limitations that would be promising future avenues of research. First, the time length in this study is probably too short to properly analyse the direction of causality between performance (i.e. growth, market success or profit ratios) and innovative capacity (or the breadth of the firm's knowledge base): longer time series would be necessary to consider time lags and causality. However, this study does show that initial size does not, in isolation, have a significant impact on future performance or the capacity to innovate. Moreover, building upon the evidence presented here, it can be argued that there is a reinforcing relationship between the broadening of the firm's knowledge base and better performance.

Second, firms' organisational knowledge should be studied in more depth. Investigating more qualitative aspects of the firm's knowledge architecture would add to our understanding of the interfaces between technological capabilities and downstream strategies. Examining what we call here the downstream-profile of research activities has proved worthwhile, but should be complemented with other elements of the firm's internal organisation of research activities.

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Appendix: List of Spanish firms

Laboratorios Abello SA
Laboratorios ASAC
Aldo Union, SA
Almirall-Prodesfarma
Laboratorios Alter SA
Laboratorios Andromaco SA
Laboratorios Alonga SA
Antibioticos SA
Laboratorios Aristegui
Industrial Farmaceutica Cantabria SA
Cepa
Laboratorios Cinfa SA
Laboratorios Cusi SA
Laboratorios Esteve, SA
Faes
Ferrer Internacional SA
Laboratorios Grifols SA
Juste SA Quimico Farmaceutica
Laboratorios Lacer SA
Lasa
Laboratorios Leti SA
Llorente
Menarini (Puig)
Laboratorios Normon SA
Laboratorios Rubio SA
Seid SA
Laboratorios SALVAT
J.Uriach & Cia
Laboratorios Vinas SA
Laboratorios Vita SA
Laboratorios Dr Andreu
Laboratorios ELMU

Appendix. Tables.

Table A. Correlations of firms' publication shares across 38 scientific sub-fields (1981-2000)

	Esteve	Ferrer	Uriach	Faes	Abello	Andro.	Alter	Antib.	Cusi	Lacer	Lasa	Menar.	Vinas	Vita	ASAC	Leti	Grifols	Salvat
Almir.	0.486**	0.416**	0.340*	0.346*	0.514**	0.275*	0.363*	0.102	0.299*	0.233	0.344*	0.311*	0.057	0.125	0.240	0.328*	0.158	0.516**
Esteve		0.564**	0.391**	0.664**	0.533**	0.451**	0.454**	0.022	0.270	0.315*	0.516**	0.509**	0.278*	0.320*	0.223	-0.031	-0.011	0.316*
Ferrer			0.357*	0.457**	0.244	0.149	0.427**	0.054	0.188	0.374*	0.501**	0.573**	-0.100	0.271	-0.017	0.002	0.062	0.304*
Uriach				0.348*	0.332*	0.198	0.546**	0.479**	0.202	0401**	0.371*	0.595**	0.027	0.497**	0.321*	0.104	0.055	0.271
Faes					0.414**	0.346*	0.636**	0.042	0.091	0.357*	0.559**	0.692**	0.013	0.365*	0.078	-0.146	-0.001	0.175
Abello						0.252	0.374*	0.103	0.159	0.218	0.246	0.426**	0.080	0.021	0.365*	0.370*	-0.036	0.246
Andro.							0.186	0.021	0.067	0.396*	0.206	0.063	0.354*	0.381**	0.289*	0.164	0.022	-0.032
Alter								0.207	0.270	0.721**	0.481**	0.620**	-0.009	0.326*	0.258	-0.039	0.402**	0.353*
Antib.									0.394*	0.295*	0.282*	0.207	0.091	0.515**	0.380**	0.100	-0.133	0.295*
Cusi										0.352*	0.138	0.270	0.138	0.260	0.441**	0.157	-0.117	0.553**
Lacer											0.313*	0.352*	0.060	0.483**	0.339*	0.075	0.399**	0.261
Lasa												0.521**	0.065	0.471**	0.124	-0.087	-0.148	0.217
Menar.													-0.009	0.326*	0.258	0.074	-0.189	0.358*
Vinas														0.191	0.334*	0.094	-0.148	0.264
Vita															0.243	0.039	-0.100	0.154
ASAC																0.363*	-0.177	0.343*
Leti																	-0.203	0.226
Grifols																		-0.148

Notes: * $p < 0.05$; ** $p < 0.01$ (one tailed). Spearman rank-order correlation coefficients.

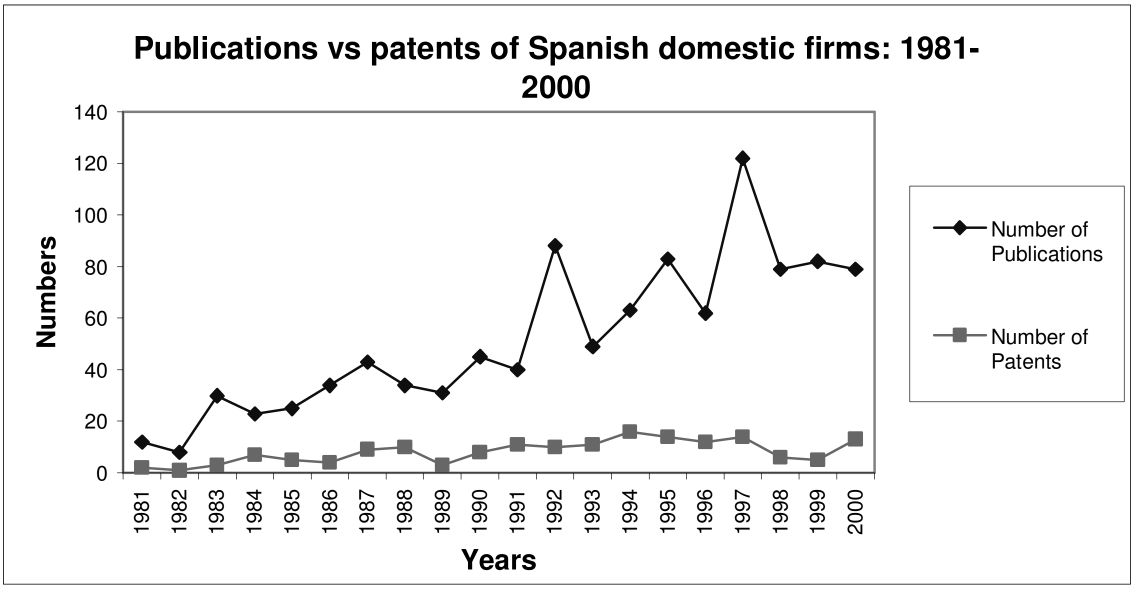
Appendix. Tables.

Table B. Correlations of firms' publication shares across 15 therapeutic categories (1 digit ATC; 1981-2000)

	Esteve	Ferrer	Uriach	Faes	Abello	Andro.	Alter	Antib.	Cusi	Lacer	Lasa	Menar.	Vinas	Vita	ASAC	Leti	Grifols	Salvat
Almir.	0.383	0.230	0.152	0.881**	-0.011	0.039	0.410	0.152	-0.507*	0.184	0.443*	0.161	0.287	0.315	0.193	-0.346	-0.138	0.338
Esteve		0.201	0.326	0.403	0.048	-0.286	0.161	0.193	-0.074	-0.160	-0.056	0.357	0.161	0.000	0.245	-0.315	0.012	0.005
Ferrer			0.515*	0.245	-0.247	0.078	0.022	0.023	-0.153	-0.025	0.401	0.081	0.369	0.457*	0.371	-0.261	0.175	0.213
Uriach				0.048	0.007	-0.076	0.485*	0.084	-0.160	0.515*	0.172	0.293	-0.135	-0.262	0.502*	-0.262	0.403	-0.267
Faes					0.025	0.132	0.420	0.116	-0.307	0.123	0.375	0.250	0.360	0.489*	0.090	-0.210	-0.307	0.417
Abello						0.337	0.254	0.331	-0.270	0.032	-0.410	0.003	-0.342	-0.184	0.342	0.516*	0.032	-0.410
Andro.							0.090	0.603**	-0.310	0.048	0.371	-0.343	-0.071	0.247	0.411	0.424	0.362	0.175
Alter								0.118	-0.233	0.640**	0.000	0.490*	0.000	-0.159	0.312	-0.159	0.233	-0.071
Antib.									-0.195	-0.195	0.026	-0.066	-0.247	-0.133	0.310	-0.133	0.320	0.003
Cusi										-0.153	-0.232	-0.271	-0.194	-0.105	-0.270	-0.105	-0.153	-0.233
Lacer											0.263	0.058	-0.194	-0.105	0.191	-0.105	0.500*	-0.233
Lasa												-0.411	0.039	0.318	0.408	-0.159	0.263	0.233
Menar.													0.350	-0.185	-0.213	-0.185	-0.271	0.238
Vinas														0.619**	-0.343	-0.133	-0.194	0.878**
Vita															-0.185	-0.071	-0.105	0.557*
ASAC																0.258	0.494*	-0.411
Leti																	-0.105	-0.159
Grifols																		-0.233

Notes: * $p < 0.05$; ** $p < 0.01$ (one tailed). Spearman rank-order correlation coefficients.

Figure 1.



Note: Documents published include citable documents (Meeting abstracts are excluded). Patent data are from USPTO (1981-2000), publications from ISI-SCI.

Table 1 Comparison between US pharmaceutical firms and Spanish firms: 1981-1993[1]

US firms[2]	Citations /paper	Pubs/100 employees (per year)	Total pubs. 1981-93	Spanish firms	Citations/ paper	Pubs/100 employees (per year)	Total pubs. 1981-93
Abbott Labs	12.6	0.4	1,968	Almirall-Prodesfarma	12.7	0.4	72
American Home Products	8.2	0.2	1,215	Alter	9.9	0.2	19
Bristol-Myers Squibb	10.1	0.5	3,386	Andromaco	13.7	0.4	20
Johnson & Johnson	17.5	0.2	2,482	Antibioticos	9.8	0.1	13
Eli Lilly & Co.	12.6	0.9	3,488	Esteve	9	0.4	53
Merck & Co.	18.6	1.4	6,135	Faes	4.3	0.3	11
Pfizer Inc.	9.4	0.4	2,030	Ferrer	5.4	0.5	70
Schering-Plough	11.9	0.5	1,321	Lasa	9	0.5	15
Upjohn	12.9	1.4	3,602	Uriach	5.7	0.5	33
Warner-Lambert Co.	8.4	0.3	1,605	Viñas	12.1	0.7	21
Mean	12.2	0.6	2,723	Mean	9.2	0.4	33

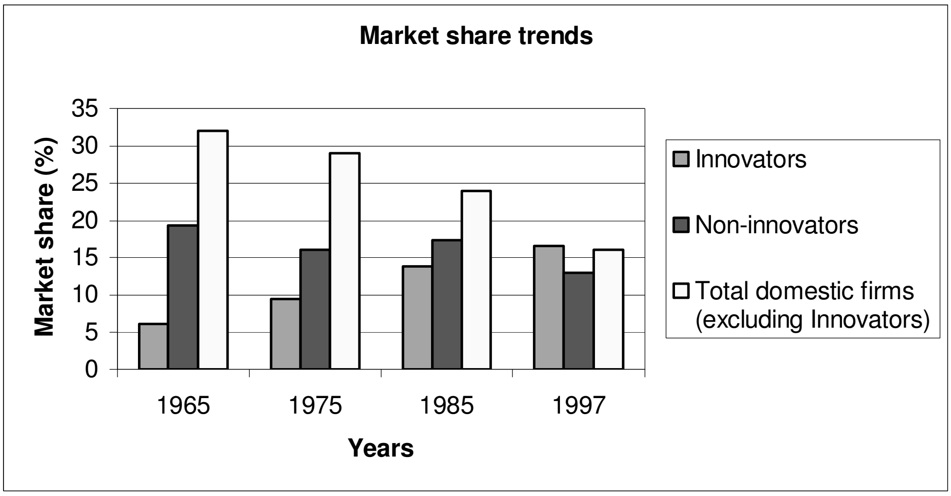
Notes: 1. Comparisons on publications refer to citable documents. 2. Figures on US firms are author's own calculations from data on publications provided in McMillan and Hamilton (2000) and data on firms' employees from Fortunes (various years). US firm data refer to the firm's US units only. Don't you need the US names more fully out or explained – we can shorten the column titles – again we talk about this – but I am trying to think ahead for the book

Table 2. List of successfully commercialised and internationally patented in-house developed active ingredients

Firm	In-house developed active ingredients	Date of international patent	Therapeutic area
Almirall*	Clebopride	Germany 1975: US 1979	Antiemetic/Antispasmodic
	Almagate	Belgium 1979: US 1984	Antacid
	Piketoprofen	UK 1976	Anti-inflammatory (topic)
	Cinitrapide	Germany 1979: US 1991	Gastroprokinetic
	Ebastine	US 1985	Antihistaminic
	Almotriptan	US 1996	Anti-migraine
Esteve	Suxibuzone	Germany 1970: US 1973	Anti-inflammatory
	Dobesilate	France 1968: US 1970	Vasotropic
	Sultosilate	Netherlands Patent. 1973: US 1976	Antihyperlipoproteinemic
Faes	Dosmalfate	US 1993	Anti-ulcer
Ferrer	Ebrotidine	US 1988	Anti-ulcer
	Dotarizine	US 1989	Anti-migraine
	Sertaconazole	US 1992	Anti-fungal
Uriach	Fosfosal	Germany 1978	Analgesic/Anti-inflammatory
	Trifusal	Germany 1977: US 1978	Anti-thrombotic
	Flutrimazole	US 1992	Anti-fungal

* The table does not include the patents granted to Prodesfarma before its merger with Almirall in 1997.
Source: Author's elaboration from Galdón (1996), Merck Index (2001) and www.uspto.com.

Figure 2.



Notes:

1. Mergers and acquisitions were addressed by restating the separate companies as a single entity for the period prior to the merger or acquisition.
2. In 1965 two firms (out of 27) from the non-innovators had not yet been founded.
3. The figures for total domestic firms include all domestic, including non-innovators but excluding innovators.
4. The remaining market share (up to 100%) corresponds to MNCs operating in Spain.

Figure 3.

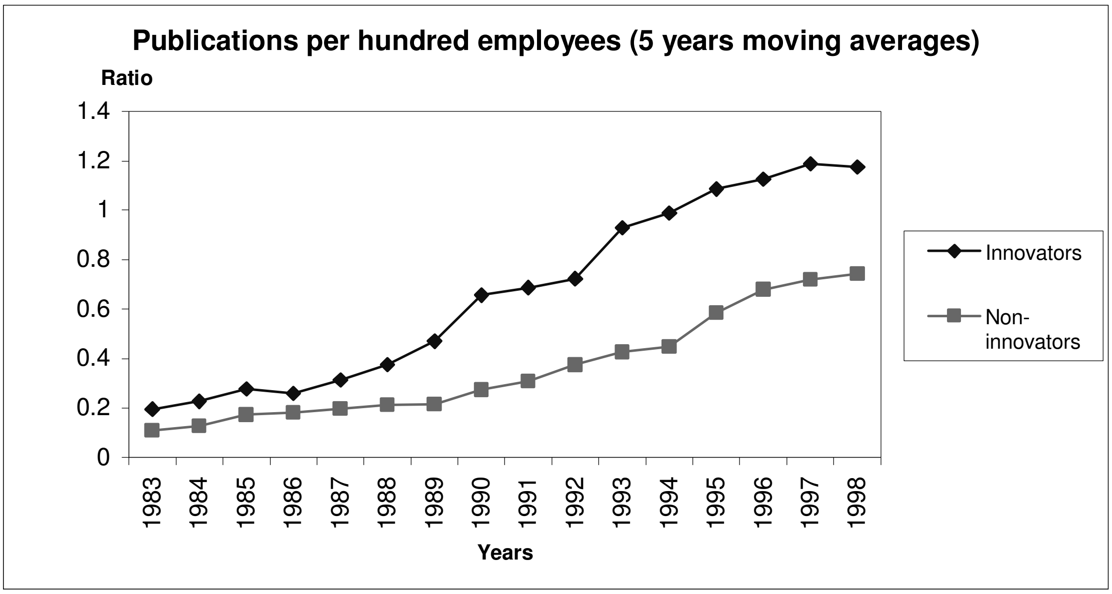


Table 3 Percentages of publications by research type

	Clinical observation (Level 1)	Clinical observation/ Clinical investigation (Level 2)	Clinical investigation (Level 3)	Basic research (Level 4)	No. of publications
1981-2000					
Innovative	5 %	12 %	62 %	21 %	528
Non-innovative	11 %	23 %	47 %	19 %	447
1981-1990					
Innovative	9 %	7 %	70 %	14 %	133
Non-innovative	2 %	16 %	59 %	22 %	140
1991-2000					
Innovative	4 %	13 %	59 %	24 %	395
Non-innovative	15 %	27 %	41 %	17 %	307

Note: The total number of publications reported in the table is lower than the total citable documents published (i.e. all documents except Meeting Abstracts) by these firms because 5.5% of the documents were published in journals that were not included in the CHI list.

Table 4. Diversification across scientific sub-fields (1981-2000)

	1 – Herfindahl Index	C1 (% of publications accounted for by the largest sub-field)	No. sub-fields with at least 1 publication	No. sub-fields/hundred employees
Innovators	0.64	57	13	1.7
Non-Innovators[1]	0.66	48	6	2.9
t-Test[2]	Not Significant	Not Significant	Significant	Not significant

Notes:
1.The group of non-innovators includes only the subset of 14 (largest publishing) firms.
2. t-Test for equality of means (2-tailed, 5% significance level). Non-parametric tests (i.e. Mann-Whitney test), testing differences in average ranks for the two groups, yielded similar results.

Table 5. Diversification across therapeutic categories (1981-2000)

	1 – Herfindahl Index	C1 (% of publications accounted for by largest therapeutic area)	No. therapeutic areas with at least 1 publication	No. therapeutic areas/hundred employees
Innovators	0.77	33	8.6	1.8
Non-Innovators[1]	0.29	79	3.4	1.1
t-Test[2]	Significant	Significant	Significant	Not significant

Notes:
1.The group of non-innovators includes only the subset of 14 (largest publishing) firms.
2. t-Test for equality of means (2-tailed, 5 % significance level). Non-parametric tests (i.e. Mann-Whitney test), testing differences in average ranks for the two groups, yielded similar results.

Table 6. Correlations of firms' publication shares across 38 scientific sub-fields (period 1981-2000)

	Esteve	Ferrer	Uriach	Faes	Abello	Andro.	Alter	Antib.	Cusi	Lacer	Lasa	Menar.	Vinas	Vita	ASAC	Leti	Grifols	Salvat
Almir.	0.961**	0.964**	0.944**	0.857**	0.029	0.219	0.908**	0.501**	0.916**	0.145	0.698**	0.945**	0.743**	0.933**	0.576**	0.045	-0.041	0.188
Esteve		0.978**	0.966**	0.921**	-0.015	0.218	0.952**	0.499**	0.891**	0.155	0.724**	0.993**	0.755**	0.940**	0.580**	-0.012	-0.068	0.187
Ferrer			0.977**	0.883**	-0.039	0.234	0.944**	0.514**	0.911**	0.200	0.746**	0.980**	0.762**	0.965**	0.590**	-0.021	-0.056	0.165
Uriach				0.868**	-0.032	0.251	0.950**	0.604**	0.914**	0.214	0.745**	0.977**	0.765**	0.980**	0.604**	-0.003	-0.062	0.219
Faes					-0.035	0.254	0.889**	0.407**	0.771**	0.242	0.756**	0.924**	0.638**	0.855**	0.491**	-0.066	-0.081	0.131
Abello						0.212	-0.036	-0.061	-0.045	-0.065	-0.050	-0.022	-0.016	-0.041	-0.004	0.931**	-0.074	-0.016
Andro.							0.220	0.041	0.179	0.547**	0.566**	0.213	0.270	0.303*	0.186	0.413**	-0.055	-0.055
Alter								0.533**	0.873**	0.325*	0.724**	0.964**	0.712**	0.920**	0.570**	-0.037	0.131	0.277*
Antib.									0.548**	0.112	0.378**	0.530**	0.379**	0.606**	0.349*	-0.056	-0.112	0.385**
Cusi										0.161	0.650**	0.895**	0.716**	0.904**	0.575**	-0.019	-0.080	0.269
Lacer											0.677**	0.180	0.077	0.277*	0.084	-0.077	0.360*	0.127
Lasa												0.734**	0.539**	0.798**	0.416**	-0.050	-0.090	0.080
Menar.													0.748**	0.946**	0.588**	-0.019	-0.079	0.235
Vinas														0.771**	0.477**	0.043	-0.104	0.310*
Vita															0.598**	-0.010	-0.065	0.143
ASAC																0.044	-0.085	0.159
Leti																	-0.099	-0.032
Grifols																		-0.101

Notes: * $p < 0.05$; ** $p < 0.01$ (one tailed). Pearson correlation coefficients.

Table 7. Correlations of firms' publication shares across 15 therapeutic categories (1 digit ATC; period 1981-2000)

	Esteve	Ferrer	Uriach	Faes	Abello	Andro.	Alter	Antib.	Cusi	Lacer	Lasa	Menar.	Vinas	Vita	ASAC	Leti	Grifols	Salvat
Almir.	0.536*	0.479*	-0.058	0.793**	-0.188	-0.203	0.347	-0.165	-0.218	-0.058	0.458*	0.129	0.372	0.363	0.439	-0.196	-0.239	0.361
Esteve		0.289	-0.101	0.177	-0.217	-0.299	0.067	0.360	-0.206	-0.215	0.590*	0.258	-0.078	-0.108	0.566*	-0.218	-0.056	-0.099
Ferrer			0.142	0.579*	-0.164	-0.199	-0.012	-0.151	-0.157	-0.140	0.465*	-0.153	0.555*	0.551*	0.320	-0.157	-0.153	0.559*
Uriach				-0.139	-0.162	-0.174	0.305	-0.054	-0.171	0.840**	0.236	-0.153	-0.174	-0.164	0.483*	-0.164	0.785**	-0.178
Faes					-0.153	-0.093	0.191	-0.148	-0.173	-0.089	0.179	0.010	0.842**	0.846**	0.104	-0.156	-0.210	0.839**
Abello						0.379	-0.062	-0.076	-0.086	-0.092	-0.122	-0.089	-0.092	-0.077	0.039	0.999**	-0.099	-0.097
Andro.							-0.072	0.022	-0.133	-0.077	0.019	-0.139	-0.071	-0.048	-0.089	0.383	-0.065	-0.015
Alter								-0.016	-0.101	0.028	-0.104	-0.01	-0.100	-0.091	0.400	-0.091	-0.015	-0.107
Antib.									-0.093	-0.103	-0.117	-0.096	-0.100	-0.084	0.050	-0.084	0.323	-0.100
Cusi										-0.098	-0.126	-0.094	-0.095	-0.080	-0.173	-0.080	-0.107	-0.100
Lacer											0.233	-0.095	-0.105	-0.088	0.338	-0.088	0.879**	-0.111
Lasa												-0.133	-0.041	-0.019	0.802**	-0.113	0.204	-0.036
Menar.													0.056	-0.084	-0.165	-0.084	-0.113	0.033
Vinas														0.989**	-0.186	-0.085	-0.115	-0.998**
Vita															-0.156	-0.071	-0.096	0.990**
ASAC																0.031	0.373	-0.196
Leti																	-0.096	-0.090
Grifols																		-0.121

Notes: * $p < 0.05$; ** $p < 0.01$ (one tailed). Pearson correlation coefficients.

Table 8. Analysis of persistence in research across 15 therapeutic categories: Spearman rank-order correlation coefficients

	1991-95/1996-2000	1986-90/1996-2000	1981-90/1991-2000
Almirall-Prodesfarma	0.66***	0.629***	0.746***
Ferrer	0.83***	0.681***	0.681***
Esteve	0.433*	0.474**	0.492**
Uriach	0.593***	0.461**	0.583**
Faes	0.589***	---	---

Notes: ***, p < 0.01; **, p < 0.05; * p < 0.1 (one tailed). First column compares the periods 1991-1995 and 1996-2000; second column compares the periods 1986-90 and 1996-2000; third column compares the periods 1981-1990 and 1991-2000. For each firm the total number of publications were as follows: Almirall-Prodesfarma, 185; Ferrer, 130; Esteve, 89; Uriach, 70; Faes, 28. Faes has most of its publications in the nineties and thus only the sub-periods 1991-1995 and 1996-2000 could be compared.

Table 9. Relationship between knowledge base diversification and performance

	Measures of performance					
	Returns on sales		Returns on assets		Ln(Sales/Employees)	
	Specif. 1	Specif. 2	Specif. 1	Specif.2	Specif. 1	Specif. 2
CONST	-0.266**	-0.422***	0.079	-0.094	7.394***	7.542***
	(0.112)	(0.11)	(0.132)	(0.128)	(0.653)	(0.653)
THERAPSCOPE	0.071***	0.082***	0.102***	0.102***	0.430***	0.376**
	(0.025)	(0.024)	(0.03)	(0.028)	(0.148)	(0.142)
SCIENCESCOPE	0.051**	0.049**	0.015	0.016	-0.270*	-0.239*
	(0.025)	(0.024)	(0.029)	(0.028)	(0.145)	(0.142)
LN(EMP95)	0.058	0.090*	-0.007	0.029	0.192	0.209
	(0.05)	(0.048)	(0.059)	(0.056)	(0.292)	(0.283)
AGE	-0.0006**	-0.0001	-0.0004	0.0002	0.002	0.0014
	(0.0003)	(0.0003)	(0.0003)	(0.0003)	(0.002)	(0.002)
THSCOPE95	0.095**	---	0.059	---	-0.392	---
	(0.043)		(0.05)		(0.248)	
SCISCOPE95	0.005	---	0.042	---	0.129	---
	(0.024)		(0.028)		(0.139)	
LN(K/L)	0.056***	0.065***	0.026**	0.037***	0.296***	0.292***
	(0.011)	(0.011)	(0.013)	(0.013)	(0.062)	(0.065)
LN(EMP)	-0.118**	-0.138***	-0.052	-0.077	-0.043	-0.079
	(0.047)	(0.045)	(0.056)	(0.053)	(0.275)	(0.270)
LN(STOCKPUB)	---	-0.039***	---	-0.048***	---	0.042
		(0.013)		(0.015)		(0.075)
INTERACT1	---	0.025**	---	0.021	---	-0.085
		(0.012)		(0.014)		(0.072)
INTERACT2	---	0.037***	---	0.052***	---	-0.021
		(0.013)		(0.015)		(0.078)
No. of observations	114	114	114	114	114	114
R^2	0.53	0.54	0.42	0.45	0.48	0.47
Adjusted R^2	0.49	0.50	0.38	0.40	0.44	0.43

Notes: * $P < 0.1$; ** $P < 0.05$: *** $P < 0.01$. Standard errors in parenthesis.
The 114 observations correspond to our 19 firms over the period 1995-2000.