FIRMS' PERCEPTION OF THE IMPORTANCE AND USE OF PATENTS AS A MEANS OF APPROPRIATING THE RETURNS FROM INNOVATION

BY

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To

Angélica,

Rochèlle,

&

Zarci

com todo meu amor e gratidão

"As intellectual property and technology have gained importance over the past two decades, the philosophical debates have melded with broader social and political discourse bearing upon the very foundation of modern society. We can expect that intellectual property will continue to press these frontiers as the information age progresses."

Peter S. Menell (2000:164)

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ABBREVIATIONS

CIS - Community Innovation Survey

EPO - European Patent Office

GATT - General Agreement on Tariffs and Trade

IDBR - Inter-Departmental Business Register

IPRs -Intellectual Property Rights

OECD - Organisation for Economic Co-operation and Development

ONS - Office for National Statistics

PCT - Patent Co-operation Treaty

TRIPs - Trade-Related Aspects of Intellectual Property Rights

UKPO - United Kingdom Patent Office

USPTO - United States Patents and Trademarks Office

WIPO - World Intellectual Property Organization

WTO - World Trade Organization

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DECLARATION

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ABSTRACT

This thesis examines firms' perception of the importance and use of patents as a means of appropriating the returns from innovation. Scholars and practitioners alike have increasingly attributed importance to knowledge assets. On the one hand, the literature has recognised the importance of appropriability mechanisms, such as patents, to protect and to capture value from those assets, though the importance of patents may vary across industrial sectors. On the other hand, the literature says little about how firms build their patent portfolio upon the knowledge they create, especially with respect to UK-based firms. Therefore, the present research extends the existing literature in at least three aspects. Firstly, it looks at what makes firms perceive patents as more or less important. Secondly, it examines how patents do (if at all) interact with other appropriability mechanisms. Finally, it looks at how firms act with respect to why, where, what and when to patent.

Despite the relevance of the services industry, the manufacturing industry is still the major source of patent applications. Thus, a firm-level study in manufacturing was chosen. The data were collected mostly from questionnaires, though a few interviews were also conducted. The adopted methodology consists of i) a series of interviews with decision-makers on patents in six pharmaceuticals firms, using a semi-structured questionnaire, and ii) two postal surveys of firms in UK manufacturing, conducted through structured questionnaires. One survey, also known as the Community Innovation Survey, was undertaken by the UK Office for National Statistics on behalf of the UK Department of Trade industry. Its purpose was to collect information on innovation-related issues. Another survey, encompassing particular aspects of patenting activities, was administered by the researcher to firms listed in the UK *R&D Scoreboard*.

Various findings were revealed, from which we here pick up a few of particular interest. Firstly, contrary to our suspicions patent numbers may be a good *proxy* for evaluating the importance of patents as a mechanism of protection, but not necessarily for measuring the level of innovativeness of a firm, although more innovative firms were found to be more likely to rank patents of higher importance. Secondly, our findings suggest that some mechanisms of appropriability are more correlated to patents than others but, overall, they lead to the same sort of conclusion: these mechanisms are more likely to work as complements than as substitutes, and this is contrary to a common assumption made in the literature. Finally, we found that i) firms seek patents mainly as a protective device against copying; ii) patents tend to be filed early in the innovation process when the prospects may still be uncertain, but appropriability can be enhanced using other patent applications, making changes to the first application and/ or making use of other appropriability mechanisms; iii) in general a broader patent scope is sought but a narrow scope can also be valuable; and iv) the attractiveness of the market is central when firms decide to pursue cross-border proprietary control of the knowledge they create.

CHAPTER 1

PRELIMINARIES

1.1 Introduction

Knowledge and its applications are pivotal to economic growth. Structural changes (e.g., globalisation, and the IT revolution) occurring in the last century have altered the perception of what is strategic (Teece 1998), so that, for example, the ratio of market to book value (Tobin's q) of many firms has increased[1] as intangible assets become more and more valuable compared to tangible assets (Lev 2001). As a consequence more academic attention has been devoted to understanding the nature and management of knowledge assets.

One way firms generate knowledge is via experimentation, and in particular by that set of activities labelled research and development (R&D). Although investments in R&D enhance firms' knowledge, any gains from such innovative effort will be discounted if the knowledge can easily be copied by competitors. Insofar as competitive advantage derives from the creation, ownership, protection and use of assets that are difficult to imitate (Barney 1991), it is in firms' best interests to avoid imitation of these assets. To this end, firms can use mechanisms that are impediments to the imitative dissipation of rents (Rumelt 1987). Those mechanisms are known as isolating mechanisms, and analogous to them are appropriability mechanisms (Teece 1986), which focus on avoiding replication and capturing value from knowledge assets.

One mechanism that helps firms in reaping the benefits from knowledge assets, and which is central to this research, is the patent. Patent systems operate by providing a legal framework within which, for a fee and for a specified geographical area, inventors own and are able to enforce property rights over the knowledge embodied in their patent grant. Although the patent system dates back to 1474 in Venice it is only in the last twenty years or so, with the increasing recognition of the importance of intangibles, that more academic attention has been devoted to patents[2]. Indeed it is now not uncommon to come across specialised literature advocating that patent strategy has become central for firms competitiveness[3] (e.g., Glazier 2000; Rivette & Kline 2000), even though there is no common ground yet, at least in academic circles, as to what a patent strategy really is.

Although the business and economics literatures have made huge progress over the past twenty years in extending our understanding of how firms use the patent system, we argue that there are still gaps in knowledge that need to be filled and several issues that still need to be consolidated. Merrill & Smith (2001:398) argue that "without an accurate understanding of the base, our conceptions of what happens in the refined atmosphere of the apex will often be distorted, or at least incomplete". It is therefore the base with which this empirical study is mainly concerned.

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[1] The median of market-to-book ratio has doubled for American companies from 1973 to 1993 (The Economist 1999).

[2] Quite a few important academic studies (e.g., Taylor & Silberston 1973; Schmookler 1965; Gilfillan 1935; Plant 1934b) predate that period, though it is fair to say that a boom of studies on patents, or perhaps on intellectual property in general, has appeared in recent days.

[3] See also the special report published in the Financial Times (2004).

The section that follows presents the objectives of this research. The third section outlines the scope of this empirical work. Then, the fourth section sets the boundaries of the research and puts the way ahead into context by providing definitions and explaining how patents differ from other forms of intellectual property rights. After exploring the basics of intellectual property, an introduction to the history of the patent system is given in the fifth section. The sixth section describes how a patent can be obtained. Finally, the seventh section gives an overview of how this thesis is organised.

1.2 RESEARCH OBJECTIVES

The prime objective of this research is to explore how firms in UK manufacturing industry use patents. The theoretical literature on the economics of patents has made various assumptions as to: the way firms use patents; the characteristics of patents that make them valuable; and about the importance of the patent system. The empirical literature has also provided insights into these issues, but these do not always reconcile with the theory (see chapter 2).

It would not be feasible to cover all aspects of firms' use of patents, and hence this thesis concentrates on a limited agenda. Based upon a review of gaps in current literature, this thesis empirically investigates what makes firms perceive patents as more or less important; how patents do (if at all) interact with other appropriability mechanisms; and how firms act with respect to four basic questions - why patent?, where to patent?, what to patent?, and when to patent?.

1.3 SCOPE OF THE RESEARCH

This research is further limited in four main directions relating to: i) socio-economic factors, ii) sector of activity, iii) level of aggregation and iv) patents encompassed. The UK was the geographic area chosen to develop this study as it has a tradition of research on patent-related issues and exhibits an intensive use of patents. According to statistics from the World Intellectual Property Organization (WIPO 2003) the UK Patent Office was the fourth largest receiver in the world of patent applications in 2003 (284,910 in total). It lagged behind only Japan, the United States, and Germany. Also the UK is still one of the major sources of technology in the world. The research thus considers UK firms, although those firms may patent outside the UK. However, the geographic area is not used to delimit the ownership of our unit of analysis (the firm). It is only used for the purpose of geographical location. Therefore, subsidiaries of foreign firms are considered in our study as long as they operate in the UK.

This study is restricted to the manufacturing sector. Despite the increasing economic importance of the services industry the output of its innovative activities is generally not patentable, and thus there is no tradition of the use of patents. The manufacturing industry is where patents are most extensively used.

In our research the firm is the unit of analysis. However, the term 'firm' is used loosely in this thesis. Although the degree of centralisation of patent activities can vary, we did not envisage any additional benefits from making a distinction between the corporate, firm and enterprise level use of patents, at least for the research objectives of this thesis.

Finally, not all patent transactions are within the target of the present research. The focus is on the firms' own produced patent portfolio, that is, on the patents they hold as a result of their own innovative effort (as opposed to purchased patents).

1.4 INTELLECTUAL PROPERTY RIGHTS (IPRS): BASICS

1.4.1 PROPERTY

According to Bouckaert (1990) the notion of property was first elaborated by legal science, and benefited, to a large extent, from the legal dogmatics tradition, which put a stronger emphasis on definitions and general principles in order to develop an intellectual framework within which legal problems ought to be solved[4]. The author argues that simplicity and complexity go hand-in-hand when it comes to defining property. It is simple because there exists a general idea that property is "something that belongs to somebody in a legitimate way" (ibid.:775). It is complex because when that general notion is applied to, for example, "the types of objects that can be owned and the legitimate methods for property-acquisition" (ibid.), other issues emerge (i.e., economic, ethical, legal, and political aspects). The academic debate, for example, barely refers to that general idea. In fact, it is argued that "someone who believes that property is a right to a thing is assumed to suffer from a childlike lack of sophistication"

(Merrill & Smith 2001:357). The conventional definition amongst scholars is that property is a "bundle of rights"[5] (Merrill & Smith 2001; Granstrand 1999; Munzer 1990).

The modern economics literature, in turn, has been driven by a slightly different approach. According to Merrill & Smith (2001:358) modern economists have assumed that property is "an *ad hoc* collection of rights in resources", and, according to the authors, this assumption has largely come into play due to Coase's seminal work (i.e., Coase 1960), although Coase himself did not explicitly define what property is. Merril & Smith (2001) argue that despite the lack of a clear definition by Coase he assumed that property is a bundle of rights to make use of resources, rather than rights to a thing that put others aside at the proprietor's discretion. Later works by, for instance, Barzel (1997) and Posner (1998) have followed a similar argument to Coase's. The former defines property as "the individual's ability, in expected terms, to consume the good (or the services of the asset) directly or to consume it indirectly through exchange" (Barzel 1997:3). The latter asserts that property is seen as "virtually every device (...) by which divergences between private and social costs or benefits are reduced" (Posner 1998:53). Merrill & Smith (2001) oppose to these views because, according to them, such a 'list-of-use' approach (as they label those definitions) departs from the central characteristic of property: its *in rem* nature. This means that it is not only the relationship to a thing that matters but

[4] The author elaborates further and provides a historical account of the development of the concept of property.

also the right to exclude others from that thing. According to the authors, this particular feature of property rights was recognized by William Blackstone and Adam Smith, for example, but it has been addressed to a lesser degree nowadays. By systematically abstracting from that feature certain aspects of property regimes may not be taken into account, the authors say, and our understanding of the subject will remain incomplete.

Munzer (1990) recognizes that there are different ways in defining property from less to more sophisticated concepts. He also adds that another point of view is that the use of property is so fragmented that a theory is impossible to be formulated, though the author himself does not favour such arguments. On the contrary, his contribution is exactly a formulation of a theory of property, which, he believes, can make use of the concepts in their various degrees of sophistication as long as the context makes clear which concept is meant. Following his advice, we believe that a definition of property as above suggested by Barzel (1997) will suffice for the purposes of this thesis. In particular, because, contrary to Merrill & Smith (2001), it is our understanding that it is implicit in Barzel's definition that the proper consumption of the services of an asset also depends upon agents' abilities to exclude other agents from the same consumption or, at least, upon their abilities to control the extent other agents may benefit from that consumption (e.g., licensing, contract-based co-operation).

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[5] Lawyers certainly see property as a right to a thing but so do accountants and management people.

1.4.2 *Intellectual Property*

Intellectual property rights can be defined as the legal rights over intellectual activities concerned with the industrial, scientific, artistic and literary fields (Cornish 1999). It is expected to a certain degree that the notion of intellectual property rights (IPRs) is a 'natural'[6] evolution from property rights on land, capital and labour (Andersen 2003). The basic notion of property has to do with the exercise of control over a particular resource by precluding others at will from the underlying resource. This basic idea derives mainly from tangible things. Intellectual property, however, stems from ideas, which by their very nature are non-physical[7]. Despite this intangible character of intellectual property, there is a degree of tangibility with respect to the various forms of intellectual property because 'ideas' must be expressed and embedded in a tangible form for the rights to be claimed.

However, if the concept of property is strictly extended from a material good to an immaterial one, there might be a misinterpretation of the characteristics of intellectual property. Both material and immaterial goods are possessed (or perhaps dispossessed) in different ways. In the particular case of intangibles there is what is called dispossession impossibility (Granstrand 1999). To exemplify, we can think in terms of what happens if a physical object and a piece of information are stolen. A material good may be returned to its owners

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[6] The evolution of the intellectual property concept, however, has followed a different trajectory from the concept of property. The former has its roots in deliberate interventions by political authorities whereas the latter emerged from a dialogue among jurists (Bouckaert 1990).

[7] It has also some novelty embodied, which does not necessarily have to be absolute (Hughes 1988).

in the sense that it will enable them to become again the unique proprietors of that particular good. This does not apply to information. The latter has an irreversible character which does not permit original owners to reach the same status of sole possession. Even if an idea is stolen its owner has not fully lost its possession, and if the idea is returned to its owner it is not disposed from its thief. In Rentzsch's words: "He who complains about the theft of his idea complains that something has been stolen which he still possesses, and he wants back something which, if given to him a thousand times, would add nothing to his possession" (apud. Machlup & Penrose 1950:12). These arguments may be strong for intellectual activities which are easy to reproduce. Many of them, however, rely upon particular resources and capabilities that *per se* preclude those who copy from any (economic) benefit. Therefore, even if a piece of information is stolen the thief may not be able to fully exploit what was stolen (Lamberton 1994). Moreover, a stolen idea, if 'returned', may add a lot to the owner's possession if followed by compensation.

Nevertheless, even being internationally accepted, this generic term, 'intellectual property rights', may not be adequate to represent the complexity and range of matter it comprises (Cornish 1999). Such a term encompasses an array of artistic and scientific manifestations of human beings, and not surprisingly we tend to associate the term 'property' to physical goods over which we can exercise a certain control. On the top of that, IPRs are also referred to in the literature (mainly economics) as monopoly privileges, in particular when the subject is concerned with the patent system. Such rights, or privileges, are ruled by a legal system at national level, though there are various international agreements that extend the rules across borders.

1.4.3 *JURISPRUDENCE*

The jurisprudence underlying intellectual property rights permits creators to have a certain time-limited right to control the use of their intellectual goods (WIPO 1997). The term during which IPRs can be enforced depends both on the type of intellectual property and the country's (or region's) legislation. For example, in the United Kingdom copyright regarding literary, dramatic, musical, and artistic works have a term of protection that is the life of the author plus fifty years. If the copyright is concerned with either film or sound recording it lasts fifty years from the year they were made. The term of protection for a patent is 20 years in the UK, but it may be extended by the means of Supplementary Protection Certificates (SPCs) to up 5 years in case of pharmaceutical and agrochemical patents[8] (Cornish 1999). In contrast, Pakistan patent protection is given for a period of sixteen years but may also be extended to ten more years (Gutterman & Anderson 1997).

The legal framework governing IPRs is particular for each country, but discussion around this matter has gone beyond territorial frontiers. And this is not a recent event. It dates back to at least the second half of the 19th century, when international treaties seeking a more homogeneous framework across countries started to be established. One of the most famous agreements is the

International Convention for the Protection of Industrial Property (so called Paris Convention), enacted in 1883 and supplemented in 1978 by the Patent Cooperation Treaty (PCT). Another one is the European Patent Convention (EPC) which came into force in 1977. The Madrid Agreement, regarding trademarks, in 1892, and the Berne Convention, regarding copyrights, in 1886, are also examples of international treaties (WIPO 1997). However, as expected, harmonisation between countries is not easy. Despite several steps towards a common agreement, IPRs have much to do with each country's own interest and bargaining power. For example, developing countries may not wish to enforce properly IPRs to enable the development of a native industry by copying what other firms in the same industry but in a different country have done. In turn, more developed countries wish less developed ones to enforce IPRs more strictly to increase returns for those firms originally set up in wealthier economies.

The acceleration of the globalisation process as of the 1980s led to an increase in conflicts regarding differences in intellectual property regimes. The increasing scope of the use of IPRs by firms originally from developed countries would demand a change in the international legal environment if international trade was to be sustained. A movement initiated in the United States in the early 1980s in order to link trade policy to intellectual property standards would reach a larger scale in the near future. In fact, the United States, the

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[8] This is not a given right. It applies only when inventions have to satisfy stringent regulatory requirements prior to obtaining market authorisation.

country-members of the European Union and Japan played a crucial role in setting up a new agenda for IP protection worldwide throughout the Uruguay Round of the General Agreement on Tariffs and Trade (GATT) in the period between 1986 and 1994[9]. That round led to the creation of the World Trade Organisation (WTO), which replaced the GATT[10] and which has as one of its founding components the Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPs). That agreement has sought to strengthen intellectual property regimes and to harmonise them across countries (Maskus 2000). An objective also targeted by the World Intellectual Property Organization (WIPO), which is a non-government institution responsible for promoting intellectual property worldwide (WIPO 1997). Nevertheless, it does not seem that TRIPs has fully met the expectations of developed countries since they are still seeking to extend intellectual property protections offered under TRIPs. This new stage, also known as TRIPs-plus, is characterized by developed countries establishing bilateral agreements with developing countries, essentially to strengthen both legislation and enforcement at levels above TRIPs demands. The United States, for example, by means of The Office of the United States Trade Representative (USTR), undertake a comprehensive examination of the commitment to and effectiveness of intellectual property protection in various foreign territories which enjoy trading privileges with the US (this process is also known as "Special 301").

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[9] Especially the US in its dealings with China, which resulted in both countries entering initially into a Memorandum of Understanding and later into several bilateral agreements.

1.4.4 CATEGORIES OF IPRS

Although the scope of intellectual property rights depends on the subject matter, all types of intellectual property share a common characteristic that can be considered essentially negative: "they are rights to stop others from doing certain things" (Cornish 1999:6). At the same time, they aim to stimulate creative activities by conferring creators a particular right on their intellectual output. On the one hand, IPRs are not a requisite for owners to exploit the result of their intellectual activity. On the other hand, IPRs of others cannot be ignored when one exploits ones own.

Intellectual property rights are grouped into areas according to the primarily subject matter involved. Traditionally there are two principal areas: i) industrial property[11] and ii) artistic and literary property. The former comprises the following categories of IPRs: patents, utility models, industrial designs, trademarks, and geographical indications. The latter comprises copyrights and neighbouring rights. Adding to these, there are also trade secrets and other *sui generis* areas[12]. Each area, and more specifically each category of IPRs, is governed by a legal framework to assure property rights over the related subject matter upon fulfilment of certain criteria.

Trade secrets refer to confidential information that may enable its owner a gain in terms of competitive advantage over its competitors that do not have

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10 The replacement was at organisational level only. The General Agreement still exists as the WTO's umbrella treaty for trade in goods.

11 This is not the same as a movable or immovable property used for industrial production.

12 This is not a definite categorisation of the areas of IPRs since there might be overlaps.

access to the same information (Gutterman & Anderson 1997). Trade secret law covers any item of information not generally known or available that the possessor wants to conceal from competitors for an unlimited time (Besen & Raskind 1991). According to Merges et al. (1997) its legal framework derives from common law property, contract and tort doctrines (plus state statutes, if applicable). The role of trade secrets as an incentive to produce valuable information is due to the limitation of i) use and ii) spread of information between contracting parties (Friedman et al. 1991). Trade secret law aims to foster the production of information that is not patentable or sometimes is too expensive to be patented (Friedman 1998). Moreover, in granting legal protection to the generator of information, as long as some effort is made to avoid disclosure, it may reduce the costs of keeping that information proprietary (Kitch 1980a). However, trade secrets do not preclude others from benefiting from the information if it is legally appropriated (e.g., reverse engineering).

Trade secret law is not present in many countries, and even in those countries where there exits a jurisprudence the framework is not homogeneous. For example, some countries do not confer protection for non-industrial information, whilst other countries do. Further, trade secrets may be governed at state level, such as in the US. This heterogeneity, however, is likely to disappear in due course as a result of the TRIPs agreement (Maskus 2000).

Patents (or invention patents) concern technology-based inventions and give holders the right to maintain some control over the utilisation of the invention for a period of time (20 years, in general). The concept of invention is an idea which permits to solve, in a practical way, a technical problem (WIPO 1997). Specifically, a patent is a legal title issued upon application which enables its holder (so called patentee) to enforce, for a limited time and geographical area, exclusive rights over an invention by excluding others from making, using or selling it without his/ her authorisation. The scope of the patentable subject matter, however, is bounded by morality, public health, and national security. Patents are granted insofar as inventions meet the requisites for patentability: i) novelty (i.e., previously unknown), ii) inventive step (i.e., non-obvious to someone with ordinary skills in the technology area the invention fits in), and iii) industrial applicability.

Originally established to incentivise individual inventors the patent system is now broadly used by corporations. But the recent 'technology revolution' may increase the participation of individual inventors in the patent arena if patent scope is to be broadened elsewhere to computer programs, as the US patent system already embraces. However, the extent that patents should include computer programs is still disputed and a lot of debate is going on. A particular issue of concern is whether computer programs can be considered inventions. Although computer programs aim to solve technical problems, and this is the concept of invention, they are instructions provided by human beings, and do not involve necessarily the scientific principles of natural sciences (i.e., physics, chemistry and biology). To date (apart from the US), the prevailing understanding is that for computer programs to be considered inventions, and hence to be patentable, they have to form an integral part of a process in one of scientific fields above. If this does not apply, property rights over computer programs need to be pursued in a different category. Most countries initially placed the matter related to computer programs in the scope of copyright. However, computer programs do not comfortably fall into this category. Moreover, copyright does not confer protection against execution of the work in private[13]. Amendments to copyright legislation have been made in many countries but to date, as far as we know, only the US have 'fully' incorporated computer programs into patent coverage (Graham & Somaya 2004).

There exists another form of property rights (the utility model) similar to patents but that embraces less stringent standards of non-obviousness. Overall, utility models (also known as 'petty patents') are awarded to mechanical inventions and for a period of time shorter than for patents (WIPO 1997). However, they are not granted in the UK (Cornish 1999).

Another form of industrial property is the industrial design. Industrial designs are concerned with the ornamental or aesthetic aspect, such as shape, pattern, or colour, of a useful article. They must be reproducible by industrial means. Otherwise, they would be considered an artistic expression and, therefore, should be protected by the copyright law. The term of protection is 25 years, at most, in the UK (ibid.).

[13] Samuelson et al. (1994) argue that a more suitable category of IPRs for protection of computer software

In addition to natural names, labels became necessary in order to facilitate consumers distinguishing one good (or service) from another. The principle that underlies marks is the creation of a relationship between goods/ services and their maker/ provider. Trademarks and service marks can be represented by a word, a name, a symbol, a device or combinations. They may consist of drawings, symbols, three- dimensional signs such as the shape and packaging of goods, audible signs such as music or vocal sounds, fragrances, or colours used as distinguishing features. They enable their owners not only to call the attention of consumers, but also to hold their attention. A firm may acquire reputation and may have its image associated to that good or service by the brand it creates. In a similar way trade names are used, but, in this case, they are names, terms or designations which represent an enterprise business as a whole, not only its goods or services[14]. Typically, marks can be renewed indefinitely upon payment of proper fees.

A related right to trademarks is geographical indication (e.g., champagne). By the same token, they are used to differentiate one good from others but, as the expression suggests, the differentiation is on the grounds of location. Geographical indications represent inherent characteristics of goods concerned with the place where they come from. Both trademarks and

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is needed. And Reichman (1994) recommends a hybrid form that combines both aspects of patents (for functional aspects) and copyrights (for the textual expression).

[14] Trademarks are not restricted to firms. They can be issued to any organisation intending to associate its image to its goods or services (e.g., non-governmental organisations). An association whose members use their image to identify themselves (e.g., CIPA - The Chartered Institute of Patent Agents) can seek trademarks, more specifically 'collective marks'. There are also 'certification marks' given for compliance with defined standards, but not confined to any membership (e.g., ISO 9000).

geographical indications aim to lower consumers' search costs (Carter 1990b). But unlike patents and copyrights, they do not protect the creation of additional knowledge (Maskus 2000). Port (1993) advocates that trademarks should not be a property right, but rather a narrow body of tort law. Perhaps the prevailing view that sustains trademarks within the property scope is that they are an efficient means of providing information in the market (P'ng & Reitman 1995).

Copyright, also known as author's rights, is related to literary and artistic works (e.g., books, novels, cinematographic productions) and it refers, as the name suggests, to the act of making copies that can only be made by the authors or with their authorisation. It is a legal instrument available to authors to prevent distorted reproduction (e.g., performance, recording, broadcast, translation, adaptation) of their works since these intellectual creations generally aim to be available to the public. The rights last the lifetime of the creator plus about 50 to 70 years, and even after these rights are sold creators may fight against damage to their works. Copyright embraces the way a work is expressed, that is, the tangible form in which the author's creation is available rather than the ideas or thoughts that have originated in it. A copyrightable work has to be original, though novelty is not a requisite. In order for someone to hold a copyright there is no need for registration as long as the work is available in any tangible form. However, it is useful to do so for the purposes of litigation (Cornish 1999). Although the purpose of copyright is to promote literary and artistic creativity and their diffusion, it is argued that such a property right is not needed for it is in authors' best interest to have their works and ideas widely disseminated (Plant 1934a). On the other hand, Johnson (1985) shows that limitations on copying enhance consumer welfare.

The 'fair-use' doctrine entails an exception to copyright in some countries. Under this doctrine, copyrighted material can be copied for educational and non-commercial research purposes. In this case, copies are allowed up to a certain limit, and the source must be cited (Maskus 2000). This uncompensated use of copyrighted material is argued to be an effective means through which transfers take place because in its absence transaction costs of licensing would prevent them (Gordon 1982).

There are also some rights which surround copyright and they are called neighbouring rights. Many characteristics of copyright are shared by these neighbouring rights, and therefore they are seen as an extension of copyright. This extension, however, depends on the type of work produced. For instance, a film to be communicated needs not only the author himself but also actors, whose interests are also to be taken into account (within the neighbouring rights framework). In essence, this category relates to those who disseminate authors' work. They comprise the rights of artists in their performances, the rights of broadcasting organisations in their broadcasts programs and the rights of sound-recording producers in the phonograms they produce (WIPO 1997).

Needless to say, the proliferation of information technologies (IT) over the past decade has imposed new challenges to the intellectual property system, and to copyrights, in particular. A classical example is the case of computer programs described earlier. The IT industry is largely surrounded by low cost and massive copying. This has raised policy concerns and a series of *sui generis* IPRs have emerged. On the top of computer programming firms, firms within the film and music industries have raised their concern about unauthorized copying and the ease with which their products can be transmitted through the internet. Amendments to copyright law have been the immediate, though not unique (e.g., computer programs patents in the US), response to the challenges imposed by this type of technology. Databases, for example, can be protected in the European Union under the auspices of the Directive on the Legal Protection of Databases [15]. By the same token, the Directive on Semiconductor Topographies protects for ten years semiconductor chips. Both integrated circuit layouts and mask works, which are a set of images fixed or encoded at a later stage of manufacturing, are eligible for protection (Besen & Raskind 1991). Biotechnology and recent advances in genetics have also demanded a more sophisticated framework. The development of new plant varieties using those techniques, for example, has meant claims for protection. This has resulted in the creation of plant breeders' rights, which is a patent-like protection but with limited scope. In general, all these examples show how difficult it is for the jurisprudence on intellectual property rights to keep pace with technological change.

[15] Reichman & Samuelson (1997) argue that this may raise hurdles for researchers and educational organisations due to the costs involved in handling the material.

1.5 THE PATENT SYSTEM: A BRIEF HISTORICAL ACCOUNT

Patent systems are designed to combat underinvestment in socially desirable inventive activities through the concession of a temporary monopoly over the outcomes of R&D, provided that these outcomes have the requirements specified by law. The extent to which this reward system[16] satisfactorily plays its role is disputed with conflicting interests and rationales at stake, but this has been so throughout the course of its development.

The evolution of the patent system followed the enhancement of the status of inventions in the Middle Ages, and the potential disclosure of the knowledge associated with their creation. In Egypt and other ancient cultures knowledge was kept secret within priestal castes. As such, no patent-like institutions were apparently needed. In Greek and Roman civilisations slaves were responsible for manual labour, and hence the inventions developed in that period did not have devoted to them much of the time from more educated people. In the Middle Ages labour started to be perceived as co-operation with God, and hence 'artes mechanicae' were incorporated in the concept of science (Kaufer 1989).

In parallel, as described by Kaufer (1989), the term 'invention' conceptually changed to a meaning closer to what we know nowadays. As the search for mineral resources was one of the main interests of societies at that time, people used to refer to 'invention' as the discovery of mining sites. Those

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In parallel, as described by Kaufer (1989), the term 'invention' conceptually changed to a meaning closer to what we know nowadays. As the search for mineral resources was one of the main interests of societies at that time, people used to refer to 'invention' as the discovery of mining sites. Those who were first to 'invent' an ore site were able to have some privileges. As soon as surface ores deposits were depleted, it was necessary to go deeper into the soil. Then, a problem arose: the presence of water. Mechanical draining devices were created to overcome that problem, and inventors were awarded with privileges. At that time the principles of favouritism and utility were extremely important for the sovereign to afford a privilege for an individual. These privileges are considered the forerunners of the current patent system, particularly when they took the form of a statute in Venice, in 1474: the 'Parte Veneziana'. The purpose of the Venice Patent Code was to foster technical advance by using monopoly privileges as substitutes for government subsidies. Such policy change was due to financial difficulties Venice was experiencing as a consequence of wars (ibid.). The 'Parte Veneziana' was, then, designed to attract engineers rather than to stimulate artisan production (WIPO 1997).

But monopoly privileges were not a 'luxury' of Venice. Other parts of Europe were moving in the same direction, such as Berne (Switzerland) where in 1467 a monopoly was granted for the manufacture and sale of paper (Price 1906). The same applied to England where, paralleling continental governments, the Crown was making use of privileges to establish new industries. But differently from other countries, there were in this country more favourable conditions to the development of a systematic patent policy. According to Price (1906:7) the chief conditions were: i) the shift of monopoly within city

[16] More discussion on incentive systems for innovation can be found in Gallini & Scotchmer (2001), Geroski (1995), Waterson (1990), and Wright (1983).

boundaries towards the Crown level, and ii) a nearly absolute sovereign who was surrounded with "the best practical economic ideas that the time afforded, and who was interested in the industrial development of the country (...)".

Price (1906) distinguishes three periods in the evolution of the English patent system. The first period was up to Elizabeth's reign during which many cases of abuse of monopoly emerged favoured by the corrupt courtiers. So, in 1597 a bill was offered in the House of Commons to combat such abuses. The intense political dispute led the Queen to interfere in the debate by informing that she herself proposed the reform. Her proclamation revoked the most abusive monopolies and the remaining cases were left to the common law to decide which grants should be allowed to stand. Just after her death, in 1603, a case in law, known as the leading Case of Monopolies[17], was adjudicated and, for the first time, the criterion of legitimacy of a patent was accepted and the common law proved an adequate remedy against monopolies.

The death of Elizabeth and the enthronement of James I was initially marked by a continuation of the effort to reform the abuses. However, the effort was not enough to clear them up. King James I himself promised to revoke some of the monopolies. Responding to a petition of the Committee on Grievances of the Parliament, James I issued a declaration known as Book of Bounty in 1610, which set out the case against monopolies. The Book of Bounty stated that monopolies were against the law of the land but the Crown reserved

[17] This case was a dispute for importing, making and selling of playing-cards.

the right to reward new inventions and the discretion to withdraw them in case of rise in prices due to such grant. However, patents were exempt from the Book of Bounty and the Crown continued to grant patents of monopoly (Boehm & Silberston 1967). Hence, the opposition in Parliament became more pronounced. Moreover, the revenues accrued to the Crown from the patent system were marginal, and there were difficulties abroad that were also besetting the Crown. This formed a propitious time for reforms, and thus investigations into the conduct of the referees of the patent cases were undertaken. So, late in 1621, the House of Lords presented a bill against monopolies, focusing mainly on the form of the system, not on its purpose. There then emerged in 1623/1624 one of the most memorable events of the history of the patent system, and, according to Price (1906), perhaps the most important legislative achievement under King James' reign: the Statute of Monopolies. This period from the Case of Monopolies to the Statute of Monopolies is the second remarkable period highlighted by the author.

After the act of 1623/1624 several monopolies were sanctioned by James I, and later on by his son Charles I. The persistent policy of increasing revenues to the Treasury was conflicting with the interests of the Parliament. The latter, in 1628, signed the Petition of Right, whose basic premise was that no taxes of any kind could be allowed without its permission. As a consequence, Charles I dissolved the Parliament in 1629. Over the next eleven years there was no Parliament and the promotion of corporations was even more intense in order to raise money, especially because Charles I did not charge fixed annual rents but rather levied a fee on each unit of goods sold. In congruence with his interests Charles I decided to resort to the custom of demanding Ship Money[18] in 1634, but this time from all counties in England and Wales. In 1640 he also called the Short Parliament primarily to obtain money to finance his military struggle, but they sat for just three weeks (hence the name) due to their opposition to his financial policies. A rebellion, which was broken out in Scotland, made him summon the Parliament again, the Long Parliament[19]. The failure of the Statute of Monopolies to consider the possibility of monopolies moving from individuals to a corporate form was, according to Price (1906), amended this time. Thus, the Long Parliament ended a number of monopolies and, with this action, those monopolies ceased to be a political grievance, at least in the early years of the English patent system.

Due to the Industrial Revolution the number of patents granted grew rapidly in England after 1760. Within the period between 1751 and 1850, for example, the figures rose from 7 to 455, reaching a cumulative total of 4223 for that period (Dutton 1984). The Industrial Revolution also brought the emergence of technology-based types of businesses. This was accentuated by a shift in the locus of inventive activities away from individual inventors towards corporate laboratories (Freeman & Soete 1997). From 1790 to 1883 other codes for granting national patents were established - e.g., the United States Patent Act in 1790 and the French Patent Law in 1791 (Kaufer 1989).

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[18] In the past, whenever there were fears of a foreign invasion, kings were able to order coastal counties to provide ships or the money to build ships.

The emergence of the patent system, however, has not stopped it from being criticised. During the nineteenth century, for example, a movement in favour of free trade acted against that system. Critics advocated that the patent system contributed to monopolistic behaviour and could be damaging to free trade interests. In 1873, a worldwide depression changed this scenario and a movement towards protectionism took place. This event probably strengthened the patent movement (ibid.).

The establishment and development of new industries followed by firms' expanding activities resulted in more intense trade negotiations at international level. The presence of strictly national patent systems, or simply its absence, constituted to a certain degree a hindrance to the growth of international trade. Then, from 1883 to date many international and regional conventions have sought a more internationally homogeneous patent code. As reported in the 'Jurisprudence' section above a new agenda for IP protection worldwide was established during the Uruguay Round of the GATT, by the Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPs). In essence, the objective is to harmonise the IP framework (including patents) across country members of the WTO. The argument, however disputed, is that in stimulating protection of inventions outside the country in which they were developed, international trade is encouraged (WIPO 1997).

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[19] It receives this name for sitting almost continuously until 1660.

1.6 AN OVERVIEW OF THE OPERATIONAL PROCEDURE

Patent systems operate at single country levels (e.g., UK, US) and at supra-national levels (e.g., EPO, WIPO), but there is no such a thing as an international patent covering all countries in the world. Thus, the first step in the process of obtaining a patent is to file an application to a patent office. Once a patent application is filed it will be either examined or registered. The latter case implies that a patent will automatically be granted and its validity will only be challenged in court. When an inventor chooses to use one of the supra-national systems, he/she has to designate the member countries of interest and pay the corresponding fees. Anyone in a country not designated is entitled to use that invention freely[20]. Moreover, as patent laws are not completely uniform amongst countries, the granting of a patent is contingent on national laws recognising the subject matter as patentable. Although there might be variations across countries, the general guidelines presented here for the UK apply to some extent to other nations.

For a patent to be granted the invention has to fulfil several requirements. Basically, there are three main requirements to be met: i) novelty, ii) inventive step and iii) industrial applicability (deadlines and fees also apply). The first requirement, novelty, means that only new inventions can be patented. If an invention is publicly disclosed before a patent application is filed it will not be

[20] An exception is the African Intellectual Property Organisation (OAPI) which issues patents automatically covering all 14 member states, unless a patent application is also a PCT application. The Eurasian Patent Office (covering 11 member states of the former Soviet Union) also issues single patents covering all signatory countries (Knight 1996).

capable of protection[21]. The knowledge previously disclosed is known as either prior art or state of the art of the technological field. The second requirement by definition is reached whenever an invention is not obvious to someone with a good knowledge and experience in the corresponding technical field. Finally, the requirement of industrial applicability implies that the invention can be put into practice (WIPO 1997).

Inventions are new ways of doing something, or offer new technical solutions to a problem, and they have different forms. Generally speaking, an invention lies in one of the two categories: i) products, or ii) processes (or methods). Processes or methods would be procedures responsible for making a product. A slight variation of a product is the composition of matter. This category of invention is peculiar to the chemical/ pharmaceutical industry where several compounds can be mixed in order to obtain a final product with properties that otherwise would not be achieved. Thus, that dichotomous definition may not be particularly informative, especially if the invention is a machine. Although a machine can also be a product if a firm makes machines for sale, it does not necessarily mean that it will be launched on the market, especially if selling machines is not the firm's core business. A firm may keep the apparatus secret and use it to make a product, since it is unlikely that competitors will have access to it (and then copy it). It also means that, like process patents, for a machine patent it tends to be more difficult to prove

[21] There are countries where the invention can be disclosed before a patent is applied for without invalidating the filing by the original inventor. This period known as 'grace period' has a maximum

infringement than for a product patent, because the latter can be found easily in the marketplace. Thus, if on the one hand, product inventions are more likely to be available in the marketplace whereas process inventions may never be accessed by competitors. On the other hand, if a process patent is infringed it tends to be more difficult to detect, and hence to enforce, than a product patent (WIPO 1997).

The UK Patent Office requests a fee to be paid on filing. And within 12 months the applicant[22] must request, and pay the corresponding fee for the preliminary examination - to check whether the application is able to proceed - and search - to look for any relevant documents which may invalidate or restrict what is claimed in a patent application. There is no need to wait 12 months to request preliminary examination and search; it can be done on filing. The date when a patent application is first filed with a patent office (priority date) is the date which a patent, if granted, will have as the beginning of its lifetime. The priority date is the date which is used to give priority to an invention. This means that if more than one inventor seeks protection for the same invention, a patent will be granted for the one who applied first. This regime of first-to-file is spread worldwide, though the US is an exception since it has a first-to-invent regime. The first-to-file regime implies that an inventor who does not file patent applications (when something patentable is available)

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length of 12 months of first disclosure, and the date of first publication is used as the priority date. This does not apply to the UK but it is under consideration (Grubb 1999).

[22] The individual, or organisation, that applies for a patent. Under the US law the applicants must be inventors. If they work in an organisation they need to legally assign all or limited rights under a patent to that organisation (assignee).

may allow other inventors to hold the corresponding intellectual rights if they apply for a patent (on the same invention) earlier (Cornish 1999).

The priority date is also the date used to check whether or not an invention is actually new. In other words, everything publicly available before the priority date is considered prior art and can be used against what is claimed. Prior art can also be used as an underlying issue to verify to what extent the inventive step requirement is fulfilled. The applicant can also decide, for whatever the reason, to file a new patent application within 12 months from priority date, but comprising the same inventive concept, claiming priority from the first one - so called internal priority (Grubb 1999).

The prosecution of a patent application is naturally preceded by the moment a firm decides that it will apply for a patent. But the best timing of applying for a patent is not simply that moment when there is something patentable; the perceived competition may impact on the timing. Thus, within the first-to-file regime a higher degree of competition may induce firms to apply for patents earlier than they would normally do, and that is why it is commonly perceived that the invention described in a patent document is likely to be based upon research undertaken under laboratory or small-scale conditions. According to the World Intellectual Property Organization (WIPO 1997), the 'true' invention (the one which a firm launches on the marketplace) is not always completely disclosed because, sometimes, it is too late to incorporate in the patent application any improvement made during a later stage, such as in a pilot. Perhaps this rationale does not apply to the first-to-invent regime adopted by the US because firms do not have necessarily to hurry to apply for a patent, as long they can prove they have invented earlier than competitors. Nevertheless, if they have interest in foreign markets they will face the first-to-file regime abroad, and thus they need to apply for patents earlier than other agents if intellectual property rights are to be held.

A hurry to file a patent application, however, may incur losses in either how broad or how strong a patent can be (Miele 2000). The importance of the timing of applying for a patent stems from the fact that the excludability that a patent provides depends also on the proper information available for the application. For example, since information is needed to support what is claimed, an early filing may weaken the validity of the patent. If the applicant has not performed the experiments that provide enough data to justify what is claimed, the patent application may be narrowed by the patent examiner during the examination stage. Thus, the patent may become easier to be circumvented due to its limited scope (or breadth). Moreover, even if the corresponding patent is not narrowed by the patent examiner it becomes more likely to be challenged. Therefore, the timing of applying for a patent is not only a matter of being earlier than others, in case of first-to file regimes, but also a matter of how the technical information available will impact on the overall business objective of that patent (Knight 1996).

A particular invention may have its function accomplished in a different manner. That is, although competitors may not be liable to exactly replicate a patented invention, they could come up with variations of the invention to perform nearly the same function without infringing anyone else's patents. However, it takes time for others to invent something that can perform the same function in a different way. And the longer it takes, the more likely it is that the first to reach the market will recoup the expenses incurred with R&D. In this sense, the degree of excludability achieved by a patent may influence the benefits derived from innovative effort.

Unless the one who applied for a patent (applicant) withdraws his/ her application, or simply abandons it, the invention will soon be disclosed. An invention is kept secret until the 18th month from the priority date (unless a request is made for earlier publication), and then the patent application is published[23]. Then, the disclosed invention becomes prior art against any application filed later, but it also implies that everyone may know what the invention is about.

After a patent application is published it will start another stage of the prosecution. The next phase is the substantive examination which is carried out by a patent examiner, who aims to investigate whether or not the invention claimed meets the patentability requirements presented in the patent specification[24]. This stage is also made upon request, within six months of the publication date. The patent examiner may or may not settle an objection against the applicant. In general, both parties reach an agreement after a period

[23] This practice has also been adopted by the USPTO since 29th November 2000. Before that date the US used to publish the patent only after it was granted (Johnson & Popp 2001).

[24] The body of text, in a patent application, that describes the invention in more detail.

of 'dialogue'[25], before a patent is issued. That period of 'dialogue' between patent examiners and inventors tends to delineate the scope of the patent (if granted), which is basically described by its claims. Claims are numbered paragraphs at the end of a patent/application that set forth the subject matter over which intellectual property rights are granted/ claimed (Hanchuk 2002). They may pose a threshold to others keen on using the invention. They are granted on the basis of what is specified in a patent application, and on the existing prior art. Therefore, they determine the degree of excludability a patent holder can get. If what is claimed only covers a few variations of the invention (narrow patent), it is likely that it will be easier for others to duplicate the function of the invention, without copying it in strict terms. If, however, an array of embodiments of an invention is described by the claims the patent holder will get a broad patent, which on average gives a higher degree of excludability. This is so because a greater scope of the patent will make it more difficult for others to develop a competing invention for a closely related purpose (Miele 2000; Granstrand 1999). Nevertheless, if a narrow patent is concerned with optimal conditions under which an invention can be performed, a narrow patent may suffice to confer a high degree of excludability (Grubb 1999; Knight 1996).

Patentees can apply to more than one national patent office individually. In this case, they can make use of one of the most important treaties: The Paris Convention. The Paris Convention for the Protection of Industrial Property is a

25 The scope of the patent is the major reason for such 'dialogue' between patent examiners and patentees.

multilateral treaty which dates back to 1883. In essence, it gives the patent applicant 12 months from the first filing (priority date) to apply for a patent to any other signatory country without risks of losing priority due to intervening prior art. Therefore, if any prior art appears within those 12 months it will not be considered against the foreign patent application. In non-signatory countries, however, any delay in applying for a patent may be crucial to the applicant forfeiting his/her rights.

Despite the advantage of this 12 months period when the country is a signatory of the Paris Convention, the option of going to national patent offices individually, as opposed to using supra-national patent offices, implies earlier patenting costs. The non-use of supra-national routes means that expenses with translations and patent attorneys services necessary to prosecute the application in the desired country have to be made earlier. This is so because the objective of supra-national routes is to make the acquisition of intellectual property easier and more uniform, and hence more beneficial (economic) conditions are offered. The European Patent Office (EPO), for example, is responsible for carrying out a single patentability examination (though patent applications are considered by a committee of three examiners), which can make it simpler and less costly compared to several individual applications. A patent to be granted by the EPO can be obtained by filing a single application in one of the official languages of that organisation (i.e., English, French or German) in a unitary procedure before the EPO and is valid in as many of the contracting states as the applicant designates. If the EPO grants a patent the applicant then may need to file translations in each designated European member country[26] and pay national fees (Grubb 1999). If the objective, however, is to protect the invention in as many countries as possible, the alternative route is the Patent Co-operation Treaty (PCT)[27], though it does not cover all the countries in the world; there are a few countries which are non-signatories of the PCT[28]. The Patent Co-operation Treaty (PCT) was first signed in 1970 and came into force in 1978. The PCT was mainly designed to make international applications simpler for the residents of the signatory countries and it seems that its popularity has increased (Grupp & Schmoch 1999). Also, in the same way as the Paris Convention, the PCT allows the applicant to file a PCT application within 12 months of the priority date.

Initially the applicant only needs to file a single document designating the states where protection is likely to be sought; neither translation nor payment of national fees is necessary, though other fees (e.g., search fees) need to be paid. The application at this first phase (so called 'Chapter I') will be submitted to a first simple examination, and a search in prior art will be made to enable the applicant to judge whether it is worth proceeding with the application. Based upon the search report the applicant may amend the patent application before it is published (18 months from priority date) in order to adjust the scope of the patent according to the prior art.

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[26] As of 2004 there are 29 contracting States of the European Patent Office: Austria, Belgium, Bulgaria, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Hellenic Republic, Hungary, Iceland, Ireland, Italy, Liechtenstein, Luxembourg, Monaco, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey, and the United Kingdom.

[27] If one is solely interested in countries that are members of the European Patent Convention, the European Patent Office is an alternative to the PCT route. The choice between PCT and EPO is not mutually exclusive.

After the application is published the applicant has to choose to proceed to a preliminary international examination report, which will give an opinion on patentability (this is the second phase and is also called 'Chapter II'). If the decision is positive, the entry into the national phase will be postponed, unless any designated country is not elected under Chapter II. If the applicant's decision is negative he/ she will face all the costs related to the national phase (e.g. patent attorneys, translation) no later than 20 months from the priority date. A positive decision may delay such costs up to 30 months from the priority date[29]. At that time, and based upon the international preliminary examination report, the applicant may decide whether or not to proceed with the application into the national phase.

Once a patent is granted it is up to the patentee to enforce it. To keep a patent in force the patent holder must pay renewal fees. In the UK renewal fees are requested from the fifth year from the priority date and for a patent to be kept in force renewal fees must be paid yearly[30] until the end of the term of protection (20 years) or until the patentee thinks it is worth it (Cornish 1999). This does not mean, however, that a patent is necessarily valid; at a certain time an objection can be presented by someone else to the Patent Office or, if not presented at that time, the patent can be challenged in court. The parties involved can also reach an out of court agreement if they realise it is feasible.

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[28] As of September 2004 there are 124 signatory countries of the PCT.

[29] If the route after the PCT is the EPO, those deadlines are 21 and 31 months, respectively.

[30] Renewal fees vary from £50 in the 5th year to £400 in the 20th year, as of 2002.

1.7 ORGANISATION OF THIS THESIS

This thesis is organised into eight chapters. This chapter has highlighted in general terms what the research is about and has provided information to complement the theoretical framework developed in the next chapter.

That chapter reviews the relevant theoretical and empirical literatures on patents. It identifies gaps in knowledge that justify this study, formulates the main research questions, and briefly describes the research methods employed to answer those questions.

Chapter three gives an insight into how UK pharmaceutical firms use patents and why patents are important for those firms. It also describes how that information was gathered.

The object of the fourth chapter is the importance of patents. That chapter addresses what makes patents more or less important within UK manufacturing industry. Hypotheses are derived from the literature review. The chapter then explains the analytical framework used to test those hypotheses. The findings derived from that analysis are presented and discussed before conclusions are drawn.

Chapter five tackles whether or not patents and other methods of appropriation are related. That issue is investigated by testing research hypotheses formulated in advance. They are presented in that chapter, followed by the econometric framework employed and the results achieved. Then, the findings are discussed and, finally, conclusions are reported.

The remaining objectives (i.e., how firms construct their own patent portfolios) of this thesis are studied in chapters six and seven. Chapter six details the methodological procedure. Chapter seven reports the results, discusses the findings in light of the literature review, and presents conclusions.

The last chapter summarises the main conclusions of this research and describes the implications of the findings for the literature, public policy and management. The limitations of this study are also discussed and recommendations for future research are proposed.

CHAPTER 2

PATENTS AND FIRMS:

LITERATURE REVIEW

AND

RESEARCH AGENDA

2.1 INTRODUCTION

The market for knowledge is highly imperfect. One of the reasons for this is the difficulty for knowledge to be traded. Intellectual property rights (IPRs), even if imperfectly, translate knowledge into a tangible form. In doing so, IPRs ameliorate the conditions under which knowledge can be traded, though this is no guarantee of a perfect market. Patents are one type of intellectual property and are concerned with technical inventions. The patent system has been under the scrutiny of economists for many years, although the question of whether or not that system fosters technical progress is still unresolved. That question, however, is not the focus of the current research; rather, central to this thesis is how firms use patents and what makes patents be deemed more (or less) important. These issues emerge as important from a review of the relevant economics and business literatures, which this chapter provides.

Economic theory has long been concerned with the grounds for the existence of a patent system, and with what should be an optimal design for that system. The economic literature also examines firms' patenting behaviour, and thus this literature is reviewed in this chapter.

The business literature has drawn attention to patents to a lesser degree than has the economics literature[31] (at least in theoretical terms). Our review of the former reveals that further rationales for the use of patents by firms can be

[31] Granstrand (2003) presents a bibliometric analysis of the contribution of various areas to the intellectual property field. The top 10 journals that have most published papers on IP are from law and economics (apart from one - natural sciences oriented).

considered, that are mainly discussed by the strategic management literature. The perspective of this literature is then reviewed after the 'Economics of patents'.

Afterwards, empirical findings from previous studies are discussed, encompassing issues such as: the value of patents; what makes some firms more inclined to patent than others; and the use of patents. As a result, several unexplored or only partly resolved issues are identified, which become the basis of the empirical research that follows. The specific methods to be employed in this research are briefly discussed later in this chapter and in more detail throughout this thesis.

2.2 Patents and the Economic Thought

2.2.1 *Technology, Knowledge and Patents*

For a better understanding of the economic motivations behind the patent system one should look first at the relevance of technology in economic theory. The descriptive paper by Young (1928) at the beginning of the last century advocated the expansion of markets as central to economic progress; either this expansion being in "finding an outlet for a potential product" or in "augmenting profits by reducing costs" (ibid.:537). What the author argued, following Adam Smith's ideas, was that the expansion of markets, through the division of labour, could lead to increasing returns to scale. Despite the verbal nature of his idea, it further stimulated the development in the economic literature of formal models incorporating such insight (e.g., Romer 1986). According to Young (1928) the expansion of markets would be a result of advances in the organisation of production that would change the industrial structure. Technology, then, could be ascribed the status of the unsettling agent responsible for such a change. This was later formalised in Solow's (1956) model which allowed for technological change to take place in models of economic growth.

Schumpeter (1942, 1934) was another economist of the last century who recognised the central role played by technological change in modern capitalist economies. He advocated that relationships in the market, and organisational structures, are renewed (or destroyed) through a process of 'creative destruction' emanating from continuous innovation. Schumpeter also believed that temporary monopoly profits accrued to those who innovate and this could explain rates of economic growth. The author also highlighted the importance of large monopolistic firms in the innovation process due to their ability to bear the costs associated with innovative activities.

Thus, it has become common knowledge that for many firms competitive advantage derives from the development and use of new technologies. Moreover, new technologies could also arise from learning by experience. Although to some degree these new technologies may be acquired from outside the organisation, many will be the result of the firms' own innovative effort often formally structured as a research and development (R&D) activity, although this is not necessarily so. And R&D activities have played an important role in promoting economic growth.

Another important contribution is by Romer (1990) who developed a model of economic growth where i) technology change was to a great extent derived from market-related actions (i.e., a model of endogenous technological change) and ii) some characteristics of technology (and which make it different from other economic goods) were incorporated[32]. These characteristics of technology pointed out by the author are analogous to the characteristics of knowledge since it is common in the literature[33] to consider technology as knowledge, in a general sense. Thus, it has become topical to discuss two characteristics of knowledge as a good. The first is that knowledge is non-rivalrous, that is, it can be used by one economic actor without precluding its use by another; a characteristic that most economic goods do not share. On the other hand, knowledge shares a common characteristic with other economic goods: it is, at least partially, excludable; excludability being a function of both the nature of knowledge and the legal system. In addition, simply having access to new knowledge is not the same as the ability to use it productively. Thus, the knowledge generated by one firm may not, necessarily, be reproduced by another firm because knowledge is to a certain degree context specific, that is, firms may differ with respect to their absorptive capacity (Cohen & Levinthal 1990).

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32 Romer (1994) has also shown that institutions play an important role in economic growth and that the costs of doing business in developing countries may reduce the number of productive activities in these countries and hence slow down their economic growth.

33 See for example Dasgupta & David (1987), and Silberston (1971).

Nevertheless, once knowledge is implemented or disclosed by one agent other agents are likely to have access to it. Therefore, knowledge will not only be an output itself but also an input to other agents. The presence of knowledge spillovers [34] may, however, prevent knowledge producers from reaping adequate benefits from their investments in its generation, especially if this is a horizontal spillover. The reasoning behind this argument is that, assuming that most firms are profit seeking and the inventor is operating under competition, if knowledge is both non-rivalrous and partly non-excludable it may be copied[35], though this may not necessarily be possible (Cohen & Levinthal 1990). To the extent that knowledge can be copied, its potential inappropriability can make inventors, or originators of that knowledge, unable to appropriate its true social value, and, therefore, they will be likely to underinvest in its production (Lamberton 1994). This, according to Arrow (1962), would not only be socially inefficient but also would hamper knowledge generators from exploiting it effectively.

As technology has been recognised as pivotal in promoting economic growth (Jones 1998), and the market for knowledge is not perfect (Teece 1998), it is not uncommon to find in economics textbooks (e.g., Parkin et al. 2000) explanations for the existence of market failures in the production of knowledge

[34] Spillovers can be defined as any indirect effect of public expenditure. Knowledge spillovers are defined as the situation in which one economic agent benefits from R&D efforts of another economic agent without tangible remuneration. Horizontal spillovers occur between competitors, and vertical spillovers flow between firms in different industries. Knowledge spillovers may also occur from one area of production to another different area (Bernstein & Nadiri 1988).

[35] Even if the costs of copying are high, they are likely to be lower than the costs incurred by the original inventor.

- such as limited information, poor definition of property rights, externalities[36], monopoly, and public goods. All of which may undermine the incentives to undertake research and development activities[37]. Thus, a typical issue of concern for policy makers is how to encourage firms to engage in innovative activities. Patent systems, even if imperfectly, are seen by many as an important element of a reward process that may foster technological change, and hence economic growth. It is largely as a reaction to excludability, or alternatively, the appropriability problem, that patent systems have been developed (Geroski 1995). They exist partly to correct distortions caused by the difficulty in appropriating the returns from the generation of knowledge (ibid.). Therefore, it is expected, assuming that firms are profit seeking, that firms pursue patent protection to ensure that they recoup benefits from their innovative effort.

The common characteristic of all patent systems, however, is that the knowledge to be patented must be disclosed to the world, and it is publicly disclosed before a patent is granted[38]. This aims to speed the diffusion of knowledge and to avoid duplication of R&D. Adding to this, disclosure avoids the presence of 'submarine patents' - patents which are kept secret, due to deliberate delays, and are only issued after the technology has been adopted by someone else, obliging the latter to pay royalties. There is thus an implicit cost to owning a patent; i.e. secrecy over the patented knowledge is no longer

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36 These are effects of a purchase or use decision by one set of parties on others who did not have a choice and whose interests were not taken into account.

37 Arrow's (1962) seminal work gives an insight into how market failures do work and undermine allocation of resources for invention.

38 The US only started to adopt early disclosure (i.e., before a patent is issued) in 2000.

available. This is the socio-economic contract between the patent holder and society (Cornish 1999).

When intellectual property rights are assigned it means that the owner can exploit it in different ways (e.g. licensing, blocking competitors' technological movement, etc.). However, the patent system may lead to distortions. As Arrow (1962) observed, to the extent that patents are successful, they may produce an underutilisation of the information disclosed. A conflict emphasised by Scotchmer (1991), who observed that stronger protection granted to the first generation of producers might lead to higher costs for the second generation of producers. Despite their relatively high importance in some industries, such as pharmaceuticals, the role played by patents as incentives for innovation seems to be less important than the market structure that precedes the generation of knowledge and that is imposed by using the knowledge (Benkler 2001). Also, an analysis of the patent system must be exercised with caution since it is a 'one size fits all' system.

Both macro and microeconomic literatures have drawn attention to the role of patents, though the latter to a greater extent than the former (Keely 2001). Despite the scant attention paid to patents by the macroeconomic literature, at least compared to the microeconomic, some attempts have been made to model particular aspects of economic growth incorporating intellectual property rights. For example, Rivera-Batiz & Romer (1991a) modelled economic growth where intellectual property rights are respected across countries. In another paper the authors focused on the impact of incomplete intellectual property rights on economic growth (Rivera-Batiz & Romer 1991b).

On the empirical side, studies at the macro level have explored the incentives from a theoretical viewpoint, but the majority of studies have been guided by the idea that patents motivate invention (Mazzoleni & Nelson 1998 a, b). Gould & Gruben (1996), for instance, observed, using a cross-country comparison, that stronger intellectual property rights promote higher economic growth rates. Maskus & McDaniel (1999), in turn, looked at the design of the Japanese patent system and realised that its features were effective in encouraging technology diffusion and incremental invention, and this helped Japan to catch up with leading countries. More recently, Kanwar & Evenson (2003) found that patents seem to spur innovation, and a lack of such an incentive structure can hamper technological change. However, it is also fair to say that during some point in time some countries such as Germany and Switzerland benefited from the lack of a regime of intellectual property rights in the sense that this allowed them to develop particular industries (Kaufer 1989). However, this may not necessarily apply nowadays, when international trade is more intense, and intellectual property rights issues are also discussed at the World Trade Organization level. But what is believed by economic historians is that only when intellectual property rights institutions were well developed did the market incentives become sufficiently large to promote widespread innovation, and hence a higher rate of economic growth (North 1981).

Although our purpose is not to explore all possible avenues of the economic reasoning on patents, the main arguments should be reviewed in more detail than the above because the social benefits and costs of awarding patents are still controversial[39]. The multiplicity of arguments, however, does not mean that crystal clear and settled stances exist, or that one approach is necessarily superior to another (even if being more commonly employed). Firstly, the various arguments sometimes overlap, and secondly, because the difficulty in empirically exploring them only allows us to have limited knowledge on the topic, theories are still inconclusive.

2.2.2 *THE ECONOMIC RATIONALE UNDERLYING THE PATENT SYSTEM*

Even if fundamental differences between physical and intellectual assets exist, the justification of intellectual property rights derives to a large extent from the notion of physical property rights. According to Benson (2002) both notions of property are bound up with what is called, in the legal literature, as the incidents of the right of property - namely, the right to possess, use and alienate[40]. Nevertheless, differences between the two types of assets are often used to criticise property rights in intellectual activities.

Despite the criticism, the intellectual property regime has been extensively implemented. The rationales for the existence of that regime (the patent system included) derive from two main schools of thought: the

[39] See also Andersen (2003), Menell (2000), and Mazzoleni & Nelson (1998a, b) for more details on these lines of thought.

[40] Alienation of intellectual property rights, according to the author, is not necessarily alienation of the knowledge embedded in the creation of ideas but rather alienation of the rights to control their use.

deontological and the consequentialist (Granstrand 1999). The former relies upon moral rights, especially natural rights, justified mainly by Locke's labour theory of property[41] and Hegel's personality theory of property[42]. The latter refers to economic consequences of the legal recognition of intellectual property rights. It justifies intellectual property on the basis of two concepts: utilitarian and teleological. The utilitarian concept has to do with consumers' preferences and the teleological concept addresses the fulfilment of the proper ends of human life. The utilitarian concept predominates in the contemporary legal and economic perspective. Thus, that line of thought is described in this sub-section[43].

Starting from historical accounts one may be tempted to conclude that the creation of the patent system was more reliant upon political issues than upon any sound economic theoretical foundation (Plant 1934b). Perhaps for some the prospect of the impact of such monopoly privileges was seen as good enough to justify its existence. Machlup & Penrose (1950) address some of the main arguments in favour of patents used throughout the nineteenth century but are possibly still in use nowadays. Although not all arguments presented by the authors were reliant on the utilitarian perspective, it was generally advocated that industrial progress was desirable and patents were an important instrument to achieve that end. Mazzoleni & Nelson (1998a, b) have recently reviewed the debate and have summarized the main streams into four broad

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[41] Locke (1690).
[42] Hegel (1821).

theories: i) patents motivate invention, ii) patents induce the development and commercialization of inventions, iii) patents enable orderly development of broad prospects, and iv) patents induce disclosure of inventions.

The first theory is based upon the idea that the anticipation of patents provides the incentives for invention to be undertaken. In the absence of a patent system there would be only marginal incentives for useful and better inventions to be pursued. In this case what is argued is that more inventing is better. However, there might be cases of duplication of innovative projects, and this may give rise to invention races, which may not be necessarily desirable. For instance, Kamien & Schwartz (1976) show that a higher degree of rivalry may induce greater R&D investments but will eventually cause the intensity of innovative activity to decline. According to Loury (1979) there is a case for patents, based upon their duration, in maximizing welfare, since they may work as entry barriers and pose a cost on newcomers on the basis of avoidance of duplication of R&D. At the same time, the winner-take-all feature of patents may induce patent races which also entail the creation of distortions[44], the so called 'common pool' problem, due to the excessive, and socially wasteful, effort to be the 'winner' (Dasgupta 1988; Dasgupta & Stiglitz 1980b). This social cost, however, can be dependent on how important patents are within particular market structures (Cohen et al. 2000; Levin et al. 1985; Loury 1979). Moreover, within this theory there is also an argument that inventors who

[43] Menell (2000) provides a more comprehensive survey of the theories on intellectual property.

[44] See also Dasgupta (1988), Dixit (1988), and Dasgupta & Stiglitz (1980a).

cannot themselves directly exploit their inventions can be motivated to invent because of the prospect of the use of their intellectual property rights in, for example, licensing out their inventions or attracting capital. The latter, in particular, can be quite relevant in order to finance further inventive activities.

The theory that investments in follow-on work needed to develop and to commercialize inventions are made possible by the award of a patent starts from the point at which previous theory ends. But the previous theory argues that patents should not be granted when invention would occur in any case. The second theory summarised by Mazzoleni & Nelson (1998a, b), however, departs from the previous by accepting that inventions would have been made even without a patent in prospect. What this theory brings under the spotlight is the timing of the patent award, because it assumes that patents are filed in the early stage of the inventing process. This assures that the economic rewards of further effort at the development stage can be appropriated if fruitful results come from this phase (Eisenberg 1996). Yet, this theory assumes that the follow-on work is unlikely to be patentable and that inventors cannot use other means of protecting the benefits of this further work. Furthermore, in accepting the patentability of inventions that would come out regardless of proprietary control, such as university inventions, there might be a burden of restricting access to inventions that would be in the public domain.

The third theory (also known as the 'prospecting' theory), in turn, emphasises the importance of a patent on an opening invention because this would permit an array of further possibilities to take place in an orderly fashion, that is, the first innovator will be responsible for the organisation of the market to develop follow-on products efficiently (Scotchmer 2005). This argument was articulated by Kitch (1977) who called attention for this feature of the patent system[45]. Different from the previous theory it does not assume that there is just one possibility at the end of the innovation process. The initial invention is seen as the beginning of a first generation of inventions that can be further developed into other generations. Under Kitch's idea, unless there is a broad patent on an opening invention, wasteful resources will be allocated to explore further possibilities left out by the opening invention. Contrary to the theory that argues that more inventing is better, this line of thought recognises the problem raised by too much rivalry (Dasgupta & Stiglitz 1980a, b; Kamien & Schwatrz 1976; Barzel 1968). Moreover, it further explores another element of a patent: its scope. Different from previous debate which focused on the length of the protection assured by a patent, this theory draws attention to, amongst other things, the breadth of the protection.

Kitch (1977) pointed out a fallacy in the arguments on patents by refuting the assumption that inventors could not claim more than they had invented. According to the author "the invention as claimed in the claims and the physical embodiment of the invention are quite different things" (ibid.:62). They, therefore, can be constructed at various levels of abstraction in order to mark the outer bounds of the rights. It is up to the inventor to substantiate his claims in the patent application in order to convince patent examiners that he

[45] Although Kitch attributes this insight to Steven Cheung.

deserves the rights over what is claimed. The broader the scope of a patent, the more difficult for rivals to come up with a competing alternative. Yet, the broader the scope of a patent, the higher the likelihood of a patent being challenged (Knight 1996). The problem in allowing a broad patent in an opening invention is that this may limit the work of others who could build upon the opening invention. According to Merges & Nelson (1990) the problem with Kitch's argument is that it ignores path dependence. That is, firms tend to work on the part of the prospect over which they have built competency, and leave unexplored some areas where they do not have the skills to develop, even if these are in a promising area. That license agreements can ameliorate this problem is correct, but the costs of technology licensing are steep, especially if they are tailored to particular licensees (Caves et al. 1983).

The last theory highlighted by Mazzoleni & Nelson (1998a, b) derives from the belief that in securing a patent one is disseminating knowledge that otherwise would be kept secret in the absence of the patent system. This cost to patent owners is argued to be necessary in order to mitigate the monopoly power derived from holding a patent; a monopoly power that may not only deviate the output from competitive levels, but may also lead to social costs of the effort expended in acquiring monopoly positions (Cowling & Mueller 1981, 1978). To some extent this theory is related to the literature that seeks to explain the number of patents a firm applies for; an issue that is of particular relevance for the present thesis, and that will be discussed in more detail later in this chapter. For the moment, it is enough to underline that patenting behaviour is also explained on the basis of the amount of information a patent discloses (Horstmann et al. 1985). As it is difficult for inventors to exploit all possibilities of their inventions, the disclosure of information in a patent grant may enable other users to come up with complements or alternatives to the patented invention, and hence increase the use of the inventions. However, this theory seems to neglect features of knowledge (presented elsewhere in this thesis) that may not make inventions completely accessible, and that allow patent holders to restrict access to the knowledge they generate and disclose in their patents.

Another line of thought in economics on why the patent system should exist rests with organisational economics (or new institutional economics). The seminal work by Coase (1937) criticizes the price system commonly used by neoclassical economics. His attempt was to answer why some transactions take place inside firms rather than in the price system. He advocates that there is a 'cost to using the price mechanism' (ibid.:390), and this is not a production cost. Firms, he says, exist because they may avoid that cost (also known as a transaction cost).

Coase's arguments have been used more intensively since the 1970s, and according to Foss et al. (2000) there are two main categories of theories of the firm. One argues that contracts are elaborated even under asymmetric information due to *ex-ante* incentive alignment; these are known as principal-agent models[46]. Another assumes that it is costly to elaborate a contract because

[46] See for example Holmström & Milgrom (1991), and Alchian & Demsetz (1973).

not all contingencies are known *a priori*; these are the incomplete contracting models[47].

Thus, although Coase's argument was concerned with why firms *per se* exist, it led to the development of analyses of the roles of contracts. One can then observe that property rights may play a role in both streams of the theory of the firm. Demsetz (1967:348), for example, argues that the 'primary function of property rights is that of guiding incentives to achieve a greater internalization of externalities'. So, property rights emerge in response to the willingness of interacting persons to adjust benefit-cost possibilities. Grossman & Hart (1986) and Hart & Moore (1990) see the firm as a collection of jointly owned assets, and by owning these assets firms are able to exercise some control over human assets. Although the arguments are based upon property rights in general, it is not difficult to extend the ideas to intellectual property rights. In the case of patents, for instance, even if employees leave a firm for another, and take their knowledge with them, their former employer will not be in a too fragile position, for he still owns the assets. Moreover, there are costs associated with the negotiation, monitoring and enforcement of the contracts that govern the transfer of knowledge assets, and that can be substantial (Williamson 1995, 1985).

Although the purpose of intellectual property is to secure the rights of owning and selling ideas, Boldrin & Levine (2002) argue that there has been a

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[47] See Williamson (1996) for instance.

distortion of that system that needs to be corrected. They argue that intellectual property rights have been extended to the rights of regulating the use of ideas, which creates a socially inefficient monopoly. Because of this and other reasons (e.g., the technology revolution that led to the emergence of Biotech and IT technologies) some have argued that patent reform is needed (Shapiro 2004; Kingston 2001). But reform requires more research to be carried out as to the costs and benefits of the patent system. Otherwise, we shall always be facing the dilemma addressed by Machlup (1958:80) who once said that "If we did not have a patent system, it would be irresponsible, on the basis of our present knowledge of its economic consequences, to recommend instituting one. But since we have had a patent system for a long time, it would be irresponsible, on the basis of our present knowledge, to recommend abolishing it".

Even if abolition of the patent system is not appropriate, perhaps a better design is. In fact, the theories above illustrate that not only the incentive system itself is of interest but also its design. The economics literature has not neglected this and it is reviewed next. The theoretical approach to design-related aspects of the patent system has also been supplemented by empirical studies (reviewed later in this chapter).

2.2.3 *Design-Related Aspects of the Patent System*

Early discourse on patents was largely descriptive (e.g., Machlup & Penrose 1950). Nordhaus (1967) was perhaps the pioneer in modelling the patent system, moving from the question of whether or not patents should be granted to the question of what design is best for that system[48]. The Nordhaus model assumed that patent duration was the pivotal policy instrument in the design of the patent system. His analysis suggested that very little could be gained from longer patent terms, but that the optimal life is very sensitive to the percentage cost reduction of the invention and elasticity of demand.

Scherer (1972) re-interpreted the model proposed by Nordhaus and assumed that the invention possibility function exhibits increasing returns (at least at the beginning of the technology cycle) rather than decreasing returns, as suggested by Nordhaus. Scherer's conclusion was that the higher the private benefit/ R&D cost ratio the shorter the optimal life of a patent can be. In a reply, Nordhaus (1972) argued that as the life of a patent has to be finite (and this is not optimal), it is better to err on the side of a longer patent life rather than on the side of a shorter one.

Kitch's (1977) argument that a broad patent should be awarded to an opening invention was soon contested by McFetridge & Smith (1980), who demonstrated that the efficiency of commercialisation is dissipated in the rivalry for the patent itself. Yet, Kitch's idea has the merit of shifting the attention to other elements of patent design that can be touched by policy makers. So, whilst patent life was key in seminal models the economics literature started a few years later to devote more attention to aspects such as i) patent scope (or breadth) and ii) patentability requirements. Furthermore,

[48] This does not mean that the previous question has been properly answered.

insights from the rivalrous competition literature have been used to further develop the early models.

Prominent works that advanced economic theory on patents are by Klemperer (1990) and Gilbert & Shapiro (1990). They looked at how patent life and patent breadth should work to increase the incentives to innovate and reduce welfare loss. Their models differ in various aspects, starting with the definition of what is meant by patent breadth. The former considers patent breadth as the region of the product space delimited by the patent grant. The latter interprets breadth more generally as the ability of the patent holder to raise price due to any aspect of patent policy. They also examine the impact of elements of patent design on different types of products. Gilbert & Shapiro (1990) focused on homogeneous products, and concluded that that infinitely lived patents are optimal if patent breadth is increasingly costly (i.e., if the deadweight loss[49] derived from such increasing breadth increases due to the patentee's growing market power). Klemperer (1990), in turn, drew attention to differentiated products. In this case, deadweight losses occur because either consumers switch to less-preferred varieties of the product or consumers completely give up (or fail) to purchase the patented product. So, the author demonstrates that if the main source of deadweight loss is substitution to alternative products a shorter patent life and a broad patent scope are desirable. On the other hand, infinitely lived, and narrow patents are preferable when the

[49] Permanent loss of well being to society that can occur when equilibrium for a good or service is not Pareto optimal.

welfare loss is caused mainly because of the substitution out of the product class altogether.

In contrast to the models which assumed that imitation could not happen when an invention was patented, later models allow for the possibility of inventions to be improved upon by rivals, that is, the possibility of someone inventing around a patent, which happens when close substitutes are brought to market and can threaten an existing innovation without infringing its patent. However, these models assume that imitation is costless. Waterson (1990) relaxes this assumption. He argues that the main impact of a product patent is to affect the choice rivals make rather than to create a monopoly. In his model the scope of protection is incomplete and what is examined is how the scope of protection should be designed to fit the variety demanded in an industry. He concludes that welfare losses are likely to be higher when a broader protection is assured in industries where variety is valued very highly.

Gallini (1992) also relaxes the assumption that imitation is costless, and proposes a model where the decision to imitate is dependent on patent life. She initially observes that optimal patent duration discourages imitation. When imitation is costly changes in patent life affect imitation decisions, and hence affect patent breadth[50]. Then, she extends her analysis and allows patent authorities to use multiple instruments in order to design a patent policy. The policy prescription of her model is that an optimal patent design under costly

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[50] Gallini (1992) uses a definition for patent breadth similar to Gilbert & Shapiro (1990) - i.e., breadth is the flow of profits earned by the innovator until the patent expires.

imitation is achieved when a broad patent is allowed and patent life is adjusted to generate the desired return from research. Nevertheless, Wright (1999) shows that the optimal patent design is not always extremely narrow or broad, it can have an intermediate breadth, provided that patent length is adjusted to ensure a certain reward. The author concludes that an optimal patent system is product specific.

An optimal patent design, therefore, depends on market structure, demand conditions, and the structure of imitation costs (which makes it impossible for an optimal patent system to be achieved by policy authorities). This also means that a patent may not confer upon its owner a well defined legal right. Economists[51] have increasingly recognized that uncertain character of patents and what has been argued is that a patent give its owner a right to try to exclude others from infringing his/ her patent rather than a right to exclude. Thus, patents possess a probabilistic nature, and as observed by Lemley & Shapiro (2005: 76) "[w]hen the patent holder asserts its patent against an alleged infringer, the patent holder is rolling the dice. If the patent is found invalid, the property right will have evaporated".

The fact that an optimal patent system is unrealistic, however, does not mean that time and effort should not be devoted to the improvement of the patent system because, even if imperfect, its existence (or not) has consequences that need to be identified. For instance, a broad patent on a prospect may assure

[51] See for example Shapiro (2003).

that the property holder will control the opening invention and some of the improvements of subsequent inventions because follow-on work may be dependent on previous activities. That may result in many potential improvements within the scope of the broad patent being underdeveloped or not even being pursued by the sole patentee (Merges & Nelson 1990). Thus, a broad scope on a prospect can result in deficient incentives to generate follow-on inventions because no one knows all possible outcomes. According to Merges & Nelson (1990:973), "the real problem is not controlling overfishing, but preventing underfishing (...)", and a broad patent may be crucial in restricting further development. Denicolò (2000) investigated the optimal degree of forward patent protection assuming that there is a patent race on the two stages of the innovation. He allowed subsequent innovations to take various forms (i.e., unpatentable and infringing, patentable and infringing, or patentable and not infringing). He observed that underinvestment in subsequent innovations occur under a regime with a degree of forward protection that results in unpatentable and infringing subsequent innovations.

The problem pointed out by Merges & Nelson (1990), i.e. preventing underfishing, is more acute when the innovation is cumulative because the opening invention may have only little value on its own but it serves as the technological foundation for valuable follow-on inventions. Thus, a concern of policy makers is how to compensate the developers of opening inventions (Scotchmer 1991). Furthermore, there is a concern for how the patent system organises the division of profit among sequential innovators (Green &

Scotchmer 1995). The extent that follow-on inventions are related to previous ones has various implications because cumulativeness is not uniform. For instance, i) a single innovation can lead to one or more follow-on innovations (e.g., the laser), ii) a second generation innovation (e.g., bioengineered products) may demand several first generation innovations (also called research tools), and iii) improvements can be only incremental in the sense that there is no clear distinction between the starting point and the later innovations (so called quality ladder), they simply keep getting better (Scotchmer 2005).

The implications of the type of cumulativeness for the design of the patent system depends to a large extent on how the parties involved are able to negotiate, that is, how their bargaining power differs. In the case of the first type of cumulativeness a license agreement (in the case of infringements) may be crucial and firms need to tackle what is perhaps the biggest problem to licensing: asymmetric information as to the value of the innovations (Gallini & Wright 1990). Scotchmer (1991) shows that several firms may compete for an *ex-ante* license (i.e., before an innovation is complete) and this may help the patent holder to recoup the costs associated with the innovation. However, if one firm is able to receive an *ex-ante* license does not mean that it is in a favourable position because as other firms are also pursuing improvements on the innovation it may end up facing 'blocking patents'[52], which make the license less valuable, provided that the improvements made by rivals are patentable.

[52] When neither the first innovator nor second innovators can commercialize the improved version of the innovation without a license agreement.

The second type of cumulativeness demands a different analysis because it cannot be argued that the second generation of innovators will have incentives to invest. In the first type of cumulativeness the first innovator will always profit by licensing the innovation. In the second type of cumulativeness there are several patent holders' interests at stake and bargaining may break down, this is what Heller & Eisenberg (1998) call the 'anticommons'. So, joint ownership of the research tools may be needed in order to enable a second generation innovation to be commercialized. Alternatively, a patent pool[53] may come into effect with the advantage that the joint price is lower than if they were sold separately by different patent owners, especially if patents in the pool are complementary (Lerner & Tirole 2002).

The incentive structure in quality ladders is different because there is no clear distinction between innovator and improver; all of them will eventually be in both positions. The problem is how to ensure that there is enough profit to be shared even after it is eroded due to competition. O'Donoghue et al. (1998) and O'Donoghue (1998) argue that to assure that the patent system achieves its purpose of promoting technical progress and rewarding innovators, both inventive step and patent breadth need to be taken into account. Thus, there might be a threshold of inventive step such that improvements below it are not

[53] Patent pools mean that intellectual property rights have been amounted to be the subject matter of cross-licensing either directly or indirectly (e.g., joint-venture set up to administer the pool). Cross-licensing means an interchange of intellectual property rights between the parties.

patented so that firms do not pursue such improvements, and the breadth[54] (leading) is large enough to cover the costs of the innovation.

Inventive step is commonly defined as the extent that an invention is non-obvious to someone skilled in the art. This is different from novelty (another patentability criterion), which is a verification of whether the invention has already been publicly disclosed before a patent application is first filed (priority date). When it comes down to the economic modelling of these concepts they are sometimes presented in a loose way, but in essence they attempt to explain the extent that a current invention differs from previous ones. The stringency (weak *vs.* strong) of the novelty requirement, as it is sometimes referred to, may impact on the technological pace for it may affect the amount of information that is disclosed in the patent specification[55] (Scotchmer & Green 1990).

A strong novelty requirement means that a more advanced innovation can be patented and marketed without infringing previous patents whereas a marginal innovation may infringe, and hence cannot be patented. A weak novelty requirement, in turn, means that smaller improvements in the technology can be patented without infringing previous patents. As a result, under the latter requirement small increments are more likely to be disclosed than are big ones. Under a strong novelty requirement a patent authority could

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[54] O'Donoghue et al. (1998) distinguish two types of patent breadth: one that protects competition from products of superior quality (leading breadth), and another that protects against competition from inferior products as compared to the patented one (lagging breadth).

demand more complete information which might not necessarily be in innovators' interest because if they so provide they will be generating externalities that may harm their *ex-ante* profits. Thus, the patent holder may decide not to apply for a patent, even if it were possible. At the same time the patent holder could benefit from this higher degree of novelty required because it would make it more difficult for rivals to circumvent existing patents as well as for them to secure another patent. Therefore, innovators could be more inclined to patent rather than to suppress information.

The model by Scotchmer & Green (1990) shows that a strong novelty requirement would be only socially preferred when it rectifies incorrect incentives for a firm to drop out of the race when it is lagging behind. The preference for the weak novelty requirement, as opposed to the strong one, is on the basis that it does not necessarily dissuade firms from research due to the dissipation of profits because if profits were to be eroded firms would not patent anyway. La Manna et al. (1989) also considered welfare implications of the novelty requirement. The authors investigated whether there was any merit in a loser-take-some reward system. That is, the novelty standard would be manipulated in order to allow for multiple patents to be granted to genuine inventors whereas true free-riders (i.e., those who have not invested in R&D) would be excluded from the reward. This permissive patent system, as the

[55] The body text in the patent application which describes the invention and which attempts to persuade patent examiners as to the fulfilment of the patentability requirements for a patent to be granted.

authors called it, was shown to be more socially preferable than the current regime.

Industrial applicability, which is another patentability requirement, has also merited attention. Based upon a three-stage model of R&D La Manna (1994) examines whether patents should be awarded to the outcome of the research stage (i.e., research prototype) or to the outcome of the development stage (i.e., developed product/ process); the degree of industrial applicability is expected to be higher in the development phase. When firms engaging in R&D compete for a single patent the research prototype system is unambiguously more socially favourable than the developed product/ process system because development costs have to be incurred before knowing whether a patent will be held. But if multiple patents are allowed to be granted either in the research or in the development phase the developed product/ process system may be more beneficial because under the research prototype system entry can be excessive.

The payment of renewal fees, which is necessary to keep a patent in force, has also been modelled. Cornelli & Schankerman (1999), for example, show that a variable patent life (through renewals) as opposed to a fixed one is welfare enhancing because a uniform (fixed) patent life provides more incentives to low-productivity firms than to high-productivity ones. But this is disputed. Scotchmer (1999), for instance, argues that patents should have a uniform life rather varying in length.

Although it is simple to understand why the theoretical modelling of the above elements of patent design is important, an empirical comparison of how different patent system designs have impacted on inventive activities of different countries is equally important. It is relevant, therefore, to investigate how firms use patents to better understand their actual impact on firms' behaviour and on economic growth. However, as patent systems are becoming more harmonised, an empirical study of how patents are used (which is considered in this thesis) may provide broader *de facto* evidence as to which are the most important elements of patent design.

2.2.4 PATENTS AND COMPETITION

Concerns about patent holders' monopoly power are not new. Gilbert & Newberry (1982) show that the patent system creates opportunities for firms with monopoly power to sustain it. As the authors observe, monopolists can maintain sleeping patents[56], and in order to deter entry they must patent before potential competitors. Their analysis may now be dated because sleeping patents are rarely obtained due to changes in the operational procedure regarding the prosecution of patent applications (even in the US where sleeping patents were observed more frequently). Nevertheless, Gilbert & Newberry (1982) reinforce Barzel's (1968) view that if patents were to be used this would be at a later date than the date under competition. Tirole (1988) argues that the monopolist's incentive to remain as such is likely to be greater than the incentive of the newcomer because monopoly profits are higher than oligopoly profits. Yet, the monopolist may not have as much to gain from innovation as potential entrants. The monopolist's innovation may dissipate all or part of the existing monopoly profits[57]. Moreover, its net incentive will be only the new profit minus the existing profit.

When newcomers enter the market they may start patent races, which inefficiently duplicate costs (Dasgupta & Stiglitz 1980a, b; Kamien & Schwartz 1976). Nevertheless, patent races are not necessarily inefficient. Fudenberg et al. (1983) argue that such races accelerate the rate of investment and put more pressure for further advances in knowledge. The authors explore intermediate patent races where pre-emption may take place but it is not automatic. They introduce experience and a dynamic strategy into race models drawing particular attention to whether leapfrogging occurs. They find out that leapfrogging depends on the degree of uncertainty, on the lags in information and on R&D. However, their model does not allow for differences in firms' research intensities.

Lippman & McCardle (1988) extend the model of Fudenberg et al. (1983) and show that followers can force the race leader to drop out. They also point out that the ability of a firm to prevent the entry of competitors by having a marginal head-start in the patent race is dependent on the natural period of research activity. Grossman & Shapiro (1987) describe a two-stage patent race model without information asymmetry. They conclude that when one firm is

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[56] Patents that are neither 'used' nor licensed to others.

ahead of another in the innovation process the leader has a greater incentive to invest in R&D than has the follower, who may have more incentives to engage in co-operation. The authors observe that when competition is quite intense co-operation may increase joint expected profits as compared to when no arrangement is set up.

However, those models assume that R&D is memoryless. That is, past R&D is irrelevant to current R&D. As a consequence, the R&D race is intense at the outset of the game and is decided as soon as a firm falls behind. Doraszelski (2003) relaxes this assumption and allows for knowledge to be accumulated over time. The author shows that a firm has an incentive to reduce its R&D efforts as its knowledge stock increases because the firm's knowledge stock enters its hazard rate[58] and depending on the shape of this function the follower may (or may not) work harder than the leader. He concludes that the pattern of strategic interaction among the racing firms is more like action-reaction[59] than increasing dominance[60].

Other models that have looked at firms' strategic use of patents have assumed that there exist information asymmetries between economic agents that can be used strategically[61]. For example, the payment of renewal fees may signal to rivals the profitability of the market. Thus, patent renewals can be used to deter entry. The patent holder may decide not to pay renewal fees to

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[57] These are what the author calls the efficiency effect and the replacement effect, respectively.

[58] This is the rate of transition out of the current state.

[59] The leader in the race invests less in R&D than the follower.

[60] The leader invests more than its rival.

eventually discourage potential entrants. On the other hand, in a non-strategic framework the non payment of renewal fees can be interpreted simply as the expected benefits from the patent being less than the expected value of its costs.

Crampes & Langinier (2000) show that the signalling feature of the renewal decision is an incentive to shorten the period over which the patent will be held because the non-payment of renewal fees may indicate a non-profitable market. Thus, if patent owners carry on paying renewal fees they may attract newcomers. Langinier (2004), however, argues the opposite when the patent regards a process. Assuming information asymmetries, the author concludes that for process innovations patent holders can strategically renew the corresponding patents in order to pretend that demand is low. According to the author the decision to keep a process patent in force may signal that the market cannot accommodate newcomers. The signal sent to potential entrants is that the demand may not be large enough that a division of profits justifies the entry costs, and hence the renewal decision creates a barrier to entry). Another strategic use comes from the pharmaceutical industry where patent holders have introduced generic substitutes for their branded (and patented) products before the actual patent expires. Kamien & Zang (1999) propose a model to explain this practice and conclude that both consumers and patent holders are better off, whereas other generic producers are not.

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[61] See Langinier (2004), for example.

Whilst economic models have examined the welfare implications mainly on the basis of the degree of protection, licensing activity (a natural consequence of protection) has been examined to a lesser degree, at least in terms of the implications of patent design for licensing. Chang (1995), for example, models what policy would be optimal in the absence of licensing agreements that emerge before an innovation is developed, i.e. when the innovation was motivated by an *ex-ante* licensing promise (contractual). His analysis determines when *ex-post* licensing agreements (i.e., when innovations are already developed) are desirable and when collusive agreements are inefficient. He concludes that collusion would be desirable only under limited circumstances, that is, when the risk of inefficient entry is relatively small and when non-infringement happens. He also concludes that courts should provide the broadest protection not only to valuable inventions relative to possible improvements but also to inventions of little value relative to expected improvements. This is so because the value of the first invention is not its stand-alone value; it is a function of the overall value resulted from improvements instead.

Nevertheless, further improvements are not necessarily developed by the original inventor, and thus patent disputes are likely to happen, especially if patent thickets[62] arise. The presence of overlapping patents is of particular concern for policy makers because those patents can lead to settlements of disputes that are not necessarily pro-competitive. Thus, analysis of those disputes is as important as analysis of disputes when just one patent is at stake (Shapiro 2001). One may conclude that firms' patent behaviour may pose challenges to competition law and policy (Dumont & Holes 2002). As patent issues may overlap with other policy instruments (e.g., competition law) attention has also been paid to those elements, and they have been incorporated into economic models[63]. For example, Shapiro (2003) proposes a model of antitrust that delineates the limits of such settlements, especially when mergers, patent pools, and negotiated entry dates are involved. In order to remedy abuses of monopoly within the patent system arena compulsory licensing has long been proposed[64]. Tandon (1982) extended the Nordhaus model by introducing licensing royalty rates. He shows that the optimal patent life is indefinite, and that the use of compulsory licensing[65] increases welfare gains. This policy instrument has been abandoned by many countries, though developing countries have been more reluctant to do so. According to Chien (2003) this policy option should not be revoked by developing countries[66].

Although firms do have incentives to pursue license agreements, this activity does not unambiguously positively or negatively impact on the extent of innovation. Gallini & Winter (1985) observed that licensing stimulates innovation in industries with low cost variability (concentrated industries), and

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[62] A dense web of overlapping intellectual property rights.

[63] O'Donoghue (1998); O'Donoghue et al. (1998); Scotchmer (1996); Chang (1995); Green & Scotchmer (1995).

[64] See, for example, Machlup & Penrose (1950).

[65] Unintended license determined by the government where a third party can make, use or sell a patented invention without the patent holder's consent.

is a disincentive where costs are asymmetric (unconcentrated industries). However, licensing is not always observed, as confirmed in models where the distribution of research results depends on firm's technological knowledge. Katz & Shapiro (1985b), based upon an asymmetric model of duopolist producers, suggest that small innovations are more likely to be licensed than those innovations over which the innovator (or potential licensor) can afford an effective monopoly, or the licensor is at least as efficient with the new technology as the licensee.

Saracho (2002) shows that royalty fees are superior to fixed-fee licensing. Rockett (1990) presents a different perspective on licensing, which sees this practice as a way for the patent holder to choose the competitors that it will face when the patent expires. That is, the patent holder affects the initial conditions of the entry game either by changing the order of entry or by crowding the market so that further entry can be deterred. This, according to the author, can be achieved by licensing early to a particular licensee in order for the latter to have a head start over competitors, and by reducing royalty fees, respectively. So, there exist benefits of licensing to stronger competitors as well as to weaker ones, and a balance has to be struck before choosing to whom to license the innovation. Yi (1998), however, shows that this trade-off does not exist if two-part tariffs[67] can be charged. The model prescription is that if non-negative two-part tariffs are feasible, the patent holder should license to the rival with higher

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[66] The author found no evidence of a decline in the innovation rate of firms affected by compulsory licenses.

absorptive capacity (the stronger one) whereas if that tariff is not viable the technology should only be licensed to the weaker competitor. Many models of licensing agreements, however, assume that licensing activities are costless. To the best of our knowledge the presence of transaction costs are not incorporated in models of technology licensing where IPRs are also analysed[68].

As observed from earlier discussion the nature of the knowledge involved in the final innovation may also impact on firms' patent behaviour because it may influence the extent to which firms will interact. When multiple interacting components are what determine the overall system performance, firms may be forced to negotiate because it is unlikely that a single firm will hold all the expertise, and hence IPRs, needed to create and commercialize the final innovation. This type of innovation is commonly referred to as complex innovations. Complexity emerges as a result of the bodies of knowledge involved (Wang & von Tunzelmann 2000), and of the number of parts that interact (Simon 1996). In short, complexity can be thought of as "(...) the number of customised components, the breadth of knowledge and skills required and the degree of knew knowledge involved in production, as well as other critical (...) dimensions" (Hobday 1998:690). For the purposes of this study, however, the definition of complexity will follow the work by Cohen et

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[67] A fixed fee plus per-unit royalties.

[68] Hill (1992) developed an analytical framework to detect when (or not) licenses should be pursued and he took into account those costs. According to him competitive intensity, number of capable competitors, profitability, the height of the barriers to imitation, and the cash flow are pivotal in the decision-making process. But that work is not within the scope of the economics literature.

al. (2002) who distinguish 'complex' innovations from 'discrete' innovations on the basis of the relative number of patentable elements in the final innovation.

There has been an increasing number of studies on complex innovations, both theoretical[69] and empirical[70]; most of them focus on complexity at the level of the number of parts that interact. It is clear from these studies that this particular class of innovations departs from the traditional understanding of radical and incremental innovation. Henderson & Clark (1990), for example, supplement the previous typology with two other categories of innovations: i) modular, and ii) architectural. The former concerns changes in the core design concepts of a technology, though the linkages between the parts are not largely affected. The latter regards changes in the relationships between the parts without necessarily introducing a new component technology. This typology not only applies to mass produced goods (e.g., VCR, cars) but also applies to a class of products coined by Hobday (1998) as CoPS (complex product and systems). The latter comprises high technology capital goods, constituted of parts (or sub-systems) that are often customised and produced in small batches, and as a consequence of high cost (e.g., air-traffic control systems, flexible manufacturing systems).

From an economic standpoint one may argue that complexity means that the utility of the core part of the system is largely reduced if not coupled to

[69] For example, Hobday (1998), Desruelle et al. (1996), and Ulrich (1995).

[70] Magnusson et al. (2003); Kumaresan & Miyazaki (2002); Hobday & Brady (2000); Bonaccorsi et al. (1999); Henderson & Clark (1990).

complementary products or services. Further, there exists increasing returns to scale in their production (Desruelle et al. 1996). Another characteristic of complex innovations is that, at least when it comes down to consumer durable goods, they can, on occasions, be dependent on network externalities, that is, the benefit that one agent derives from a product depends on the number of other agents using that product. This network effect can be a direct one, that is, the total number of subscribers to a network determines the value of access to that network, or it can be an indirect effect, which value is conferred by the number of agents adopting compatible products (Church & Gandal 1993; Katz & Shapiro 1986, 1985a). This brings new challenges to both intellectual property and competition policies because a few firms may use patents in standard-settings, and thus forestall competition after the standard is established.

The very nature of patents as part of a legal framework, and the various licensing issues that emerge from contractual arrangements where patents are involved naturally lead to legal disputes. Interest in patent litigations is a recent phenomenon, although the economic analysis of law is older (e.g., Cooter & Rubinfeld 1989). Both empirical[71] and theoretical literatures on the economic analysis of patent litigation have grown over the past decade or so. To the best of our knowledge, Meurer (1989) was one of the first to model litigation when patents are concerned. His model analyses when patent licensing happens as a consequence of settlement agreements due to risks of patent invalidity. The

[71] Graham & Somaya (2004); Somaya (2003); Lanjouw & Schankerman (2001a, b); Lanjouw & Lerner (2000); and Lerner (1995).

basic condition is that the patentee has private information about the validity of the patent, and makes a take-it-or-leave-it settlement offer to a single competitor. He finds that when a patent is valid the patent holder never licenses, whereas when the patent is invalid the patent holder may or may not refuse to license. Choi (1998), in turn, models the enforcement of patents when there is more than one potential entrant. As multiple imitators may either try to free ride on information, or to pre-empt each other, information becomes more relevant than in the paper by Meurer (1989). The author shows that information about patent litigation may affect entry decisions of potential entrants. Thus, legal costs are not the unique factor affecting firms to opt for a settlement with potential patent infringers.

Aoki & Hu (1999) more explicitly incorporate legal costs in their model and show that a legal regime where costs are high for both parties (patentee and potential imitator) is socially optimal, though a regime with moderately high legal costs provides a greater incentive to innovate. The authors also show that the probability of winning contributes to whether patentees license (or not) their technology. Llobet (2003), in turn, shows that when innovation is cumulative and firms hold private information about the quality of their inventions, a higher level of protection granted by the courts may be detrimental to the patent holder because it reduces the entry of potential infringers that would otherwise license the patented invention. Crampes & Langinier (2002) study how a patent holder's monitoring effort influences the entry decision of the imitator both when the parties involved decide simultaneously and when their decisions are sequential. A counterintuitive result they found is that the likelihood of entry can increase with the penalty for infringement.

Schankerman & Scotchmer (2001) investigate the deterrence effect of legal mechanisms of protection of intellectual property when the invention would normally be licensed (e.g., research tools). They studied two enforcement regimes[72], namely liability rules (damages) and property rules (injunctions[73]). They find that in that case neither enforcement regimes deter infringement. Although the authors found that, depending on the length of time an injunction takes to be claimed, liability rules can be superior to property rules, these results seem to reinforce the view that patents are to a large extent probabilistic in nature and the outcome of patent disputes is not necessarily known. Regardless of the regime used what can be assured is that there is a cost for each decision that the patent holder makes when infringement is detected. For example, if the patent holder allows the infringer to stay in the market the market power of the patent holder can be reduced. If the decision is to go to court, legal expenses will be incurred. And even if an agreement is reached, this involves settlement costs.

[72] The doctrines that govern liability rules are 'lost profit' (the infringer has to reimburse the patentee), and 'unjust enrichment' (infringers hand their gains over patent holders).

[73] Injunctions are equitable remedies in the form of a court order that either prohibits or compels a party from continuing a particular activity. That is, they stop the use of the patented knowledge. The party that fails to adhere to the injunction faces civil or criminal contempt of court and may have to pay damages or sanctions for failing to follow the court's order. They allow patent holders to sue infringers even before the latter has brought a new product to the market.

The basic premise that patents spur innovation has long been modelled assuming that the alternative to patents is to keep things secret. Using that assumption, Takalo (1998) studied the impact of patent breadth and length on innovation. In a duopoly model where the innovator has the option for patenting or keeping the innovation secret he shows that patents are used when patent breadth is large, and secrecy is encouraged when spillovers are high. On the basis of the same assumption Takalo & Kanniainen (2000) have shown that patents can actually slow down technological progress. They argue that in holding a patent the losses that patent holders incur with rival's introduction of competitive innovations are reduced. As a consequence, patent holders may delay market introduction of new innovation. Atallah (2004) used a two-firm competition model where firms invest in cost-reducing R&D to describe when secrecy is likely to take place. The author models decisions on R&D, secrecy, and prices. The results suggest that legal and strategic protections are substitutes since increase in spillovers increase secrecy.

In contrast to the above models Cassiman et al. (2002) conclude that legal and strategic protections are complements. They model the allocation of resources to basic and applied R&D, and to secrecy. They model the behaviour of an innovator that faces a fringe of imitators. The imitators, however, do not innovate, and hence there is no strategic interaction. Despite this limitation their results seem to be in line with their own empirical findings for Belgian manufacturing. Anton & Yao (2004) have recently proposed that firms do not use either patents or secrecy, rather their assumption is that what a firm has to decide is how much knowledge will be disclosed. In this case, the innovator's strategy is mixing patenting and secrecy.

This research empirically addresses whether patents, secrecy, and other appropriability mechanisms (e.g., IPRs, lead-time) are complements or substitutes. In doing so, we hope to shed some light on the dispute above, especially on the 'Hamlet' problem of patents *vs.* secrecy, which we are sceptical about. We suspect that the Anton & Yao (2004) proposition might be correct, especially if further insights from the rivalrous competition literature are brought into the debate. That literature recognises the role of patents as entry deterrents, although they were initially seen simply as 'innocent' entry barriers (i.e., only used as a side effect of profit maximisation) rather than strategic entry barriers erected purposely (Salop 1979). The work by Horstmann et al. (1985) emphasised the strategic role of patents due to the information they disclose to rivals. They concluded that a patent is unlikely to be pursued when it conveys stronger information to imitators. In order to influence this disclosure and promote the diffusion of technical knowledge, which is one of the objectives of the patent system, policy makers can manipulate the design of the system, and according to Matutes et al. (1996) patent breadth is more important than patent length for that purpose.

Recent economic models[74] have drawn attention to the role played by patents (and other forms of intellectual property) in the firm-university

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[74] See for example the issue number 21 of the International Journal of Industrial Organization in 2003.

relationship. This is also known as the economics of intellectual property at universities, and is claimed to be at the very heart of the knowledge-based economy (Foray & Steinmueller 2003). Although there is an increasing number of empirical studies[75] of the economics of intellectual property at universities, the theoretical foundation is still slim. Some aspects that have been theoretically analyzed are, for example, whether university researchers should engage in that type of partnership (e.g., Beath et al. 2003), or the roles of university technology transfer offices (TTO), university scientists, and the central administration of the university in the licensing process (e.g., Jensen et al. 2003). As our primary concern in this thesis is with competition between firms, we narrow our focus on whether that type of collaboration impacts on intellectual property issues. The sparse theoretical development in this area has not advanced our knowledge enough. Panagopoulos (2003), who has modelled the conditions under which firms should engage in profitable research joint ventures (RJVs) with universities, suggests that firms and universities involved with new technologies are more likely to form RJVs. A reason for this, according to his model, is the opportunity cost of an agent in sacrificing his own research initiatives to collaborate with another agent. The opportunity cost will be lower for firms working with innovations closer to science and that quickly evolve because of the degree of intellectual property protection. In dealing with this type of technology firms are able to anticipate that it is difficult to fully appropriate the returns to R&D because, in general, it also needs to benefit from

[75] Agrawal & Cockburn (2003); Monjon & Waelbroeck (2003); Mowery et al. (2001); Henderson et al. (1998).

knowledge spillovers. But this does not mean that firms will not put a value on patents because in having proprietary control over the technology firms may have better control of the extent of knowledge spillovers due to various contractual arrangements where intellectual property rights issues are also embedded. So, it is expected that firms engaged in RJVs with universities are more likely to value patents higher than those who are not engaged in these activities. Whether this expectation is actually fulfilled empirically is not known but it is investigated below in this thesis (chapter 4). Next section, however, reviews how intellectual property rights, patents in particular, can affect a firm's performance (relative to rivals), an issue of primary concern to the literature on strategic management.

2.3 PATENTS, KNOWLEDGE AND STRATEGY

Strategy is concerned with understanding the causes and forces that explain differences in performance between organisations (Pettigrew et al. 2002). Thus, according to Bowman et al. (2002), two questions are central to strategy: i) why are some firms more successful than others? and ii) how can a given firm be made more successful? The question that follows is whether there is a role to be played by patents in those differences in performance. The elements that make up the design of a patent system are largely the same as the tools firms can use to enhance their competitiveness (at least when it comes to patent issues). This means that the strategic role of patents in terms of their capacity to influence firms' interactions also depends on those elements.

As observed by Bowman et al. (2002) the strategy field is characterised by pluralism, where concepts and theories have been borrowed from various disciplines. The authors point out three academic styles in the field: one that comes from the institutionalists, one that is provided by economists, and another derived from behavioural scientists. They argue that the views of these three groups have become more integrated over the years. As it would be an heroic task to review all the literature, and this would not be needed for the purposes of this research, we have narrowed our focus.

Although previous contributions, such as the structure-conduct-performance pictured by Porter's five forces analytical framework[76], are acknowledged, we place special emphasis on what has evolved over the 1990's. The reason is that we do not need to go further than that to notice the role of patents in the field of strategy. Within Porter's framework protection is emphasised in terms of positioning in an industry, and a possible way to accomplish this task would be through the creation of entry and mobility barriers, and this is where property rights fit in.

One of the more recent concepts in the strategic management literature is the resource-based view of the firm (RBV), which has grown in popularity over the last decade, and whose roots trace back to earlier works of industrial economists (e.g., Penrose 1959). The RBV derives from these studies and was first coined by Wernerfelt in the mid-1980s (Wernerfelt 1984). This view of

[76] Porter (1985, 1980).

strategy contends that superior performance is a result of firm-specific resources[77] (i.e., assets, capabilities, competencies, information, and reputation). To the extent that those resources are unique and difficult to imitate, they confer sustainable competitive advantage on the firm (Barney 1991). Reed & DiFillipi (1990) suggest that tacitness, complexity and specificity are key characteristics of resources that make them difficult to imitate. But even if competitors attempt to somehow acquire or develop those resources there are impediments (isolating mechanisms) to this behaviour (Rumelt 1987). One of those impediments, and central to this thesis, is the patent, though it is for a specific purpose and of variable effectiveness. Perhaps as important as identifying patents as isolating mechanisms is to observe that they may help in guarding against the dissipation of value. In doing so, value is not only created but also appropriated (Teece 1986).

More recently, a similar argument has emerged where knowledge, as opposed to resources, has been under the spotlight as the most strategically relevant resource (Grant 1996). The knowledge-based view of strategy (KBV) advocates that the firm is a repository of knowledge. As such, differences in knowledge stock, and in its development and deployment, lead to different performances[78]. Thus, this line of thought views superior performance as dependent on the ability of firms to be good at innovation, protecting intangible knowledge assets and using them (Teece 2001). Again, patents are at the very

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[77] See Barney (1991); Prahalad & Hamel (1990); Wernerfelt (1984).

[78] See Foss (1996 a,b); Grant (1996).

heart of strategy by deterring imitation and helping the appropriation of the value derived from knowledge, at least from technologically-related knowledge.

There are elaborate definitions[79] of what knowledge is, but, as suggested by Polanyi (1967), it is most typically defined in two categories: i) explicit (or codified) knowledge, and ii) tacit (or implicit) knowledge. The former is knowledge about facts and theories, can be transmitted via formal systematic language, and as a consequence can be captured more easily than tacit knowledge. The latter is experientially based, that is, it is personal, it is specific to a domain, and more difficult to be formatted, communicated and shared with others.

Even if for the purposes of this thesis we do not envisage any additional benefit in a more elaborated treatment of knowledge, it is important to note that the above dichotomous categories lead to a comparison of ease/ difficulty in transmission/ use of knowledge that may be misleading. As observed by Malerba & Orsenigo (2000) such a dichotomy does not address a proper comparison because tacitness and codification are not simple properties of knowledge itself. They are partly influenced by economic incentives and other social/ institutional processes. Therefore, the extent that knowledge is explicit/ tacit may vary in degree, and these categories are perhaps the extreme points of a spectrum[80] (Saviotti 1998).

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[79] See, for example, Casselman & Samson (2004), Nonaka et al. (2001), and Malerba & Orsenigo (2000).

[80] For a further treatment of knowledge management see Nonaka & Teece (2001).

Although imitation barriers, such as patents, can influence the creation of sustainable competitive advantage this advantage is perhaps mainly achieved because firms recombine knowledge in creative ways to pursue new market opportunities (Kogut & Zander 1993). Firms, therefore, may specialize in the creation and transfer of knowledge (Kogut & Zander 1996), even if knowledge spillovers are associated with the way research is structured amongst firms in a particular industry (Keep et al. 1994). The life cycle of technology may also influence the codifiability of knowledge and this may have implications for competitive advantage. Cardinal et al. (2001), for example, argue that firms in developed and developing fields tend to have different processes through which knowledge is generated and transferred throughout the value chain (R&D, production, marketing sales).

If firms evolve in part through the combination of knowledge (Kogut & Zander 1996), it is in their interest to control how knowledge is transferred both within and outside their boundaries. However, it is far from easy to build up organisational structures and management practices that develop and leverage knowledge within a variety of innovation contexts (Collinson 2001). Even intra-firm transfer of knowledge has proved to be difficult (what is referred to in the literature as knowledge 'stickiness'). Szulanski (1996) argues that organisations 'do not know what they know' because of knowledge-related barriers (e.g., absorptive capacity, difficulties in the relationship between source and recipient) rather than their lack of willingness to learn. Kogut & Zander (1992) observed that intra-firm transfer of tacit knowledge is more likely to happen than interfirm transfer. Moreover, they detected that tacit knowledge is in fact slower to be transferred. Nevertheless, despite knowledge being difficult to transfer an innovator should be concerned about other firms having access to his/ her knowledge. Other firms' own knowledge may enable them to codify, absorb, and transform new knowledge at various degrees, and perhaps on occasions derive more value from the transferred knowledge than its originator. As noticed by Collinson (2001), in order to master knowledge accordingly, firms need a better understanding of how organisational and management characteristics influence the development, deployment, and integration of knowledge. The ease/ difficulty with which knowledge can be transferred poses challenges to managers who need to control the flow of knowledge if the returns of the creation of this knowledge are to be appropriated. Thus, because of the fuzzy boundaries of property rights and of the nature of knowledge, a key challenge for top management is to figure out how to protect and retain the firm's own knowledge. As Teece (2001:141) observed, "it is not just an intellectual property issue that can be delegated to the law department".

Although Hall (1993, 1992) has linked strategy to intangibles, as far as we know there is no formal theoretical treatment of what a *de facto* patent strategy is, at least in the strategic management literature. To the best of our knowledge a first attempt to answer this question has been made by Somaya (2002). Even if still in progress, his work has the merit of being the first to outline patent strategy as encompassing several decisions on issues relating to obtaining patent rights, enforcing these rights, and licensing them. In addition, the author points out that there is a 'non-market' element, which is the firms' attempt to influence policy makers.

The various uses of patents reported earlier in this thesis[81] (e.g., licensing, signalling) as well as the way patent portfolios can be organised[82] are all elements of a patent strategy. Granstrand (1999) observed on the basis of case studies of large Japanese and Swedish firms several ways patent portfolios are constructed, which the author described as generic patent strategies, and they are as follows:

- *Ad hoc* blocking - this strategy derives from an informal approach to patenting; it is characterized by limited resources and/ or little attention to narrow patents and portfolio effects. The result is low effectiveness as a mechanism of protection because rivals can easily invent around the patented invention.

- Strategic patenting - despite being ambiguous this term means that a single patent with extremely high or (economic) unfeasible invent around costs is obtained. This type of patent therefore has large blocking power.

- Blanketing - this is when a series of patents are taken out in a more or less structured way but with the purpose of turning an area into a minefield of patents.

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[81] See Teece (2000), for instance.
[82] See Glazier (2000), Rivette & Kline (2000), and Knight (1996).

- Flooding - this strategy is similar to blanketing but patents are taken out in a less structured way. Both strategies are more likely to be observed in emerging technological fields, and are motivated mainly by the high uncertainties regarding profitable R&D directions and the economic importance of the scope of a patent.

- Fencing - this strategy consists of a series of patents ordered to a certain extent with the purpose of holding a proprietary control over a range of different alternatives for achieving a similar functional result. That is, various substitutes for an invention are patented.

- Surrounding - this practice refers to patenting of complementary elements of a central patented invention, which may be held by the same inventor or by someone else. If surrounding and core patents are held by the same inventor s/he may preclude competitors from having access to the technology. If surrounding and core patents are held by different inventors, those who have control over complementary technologies for the core invention may induce a negotiation because the patent holder of the core invention will not have all the rights necessary to commercialize the innovation.

But a patent strategy should not be completely disentangled from other intellectual property issues. Reitzig (2004c) enumerates various examples where intellectual property strategies are used to create and sustain competitive advantage. The capture and protection of value from innovation, however, goes beyond the use of IPRs because, at least with respect to appropriation, firms are able to use other appropriability mechanisms. Therefore, we suspect intellectual property strategies are developed within the remit of firms' appropriation strategies, which for the purposes of this study consist of the choice and planning as to the way certain mechanisms will be deployed to capture value from innovation and to protect that value from being dissipated due to the intervention of other agents (e.g., imitators, competitors). Those mechanisms are, in essence, ways firms use to appropriate the value derived from the knowledge they (or someone else) developed. Examples of appropriability mechanisms are: being first to market, using IPRs, moving down the learning curve, holding co-specialised assets, keeping things secret, generating very complicated innovations, creating costs to consumers in switching to other innovations, and so on. Insofar as several mechanisms of appropriability exist, firms are likely to use them to the extent that the returns from innovation are increased by their use (assuming that firms are profit seeking), that is, they are used to capture and to protect the value from innovation.

Nevertheless, and different from economics (as reported earlier in this thesis), the above literature does not seem to have drawn much attention to the knowledge disclosure character of patents; the focus has been mainly on appropriability on the basis of excludability. As regards patenting Hufker & Alpert (1994) report what managers should look at when dealing with it (e.g., licensing, related patents, and predictable improvements). A clear message from their paper is that information disclosure is central[83], and this should not be overlooked when bringing patents to the strategic framework.

Recent work by Foss & Foss (2002) seems to fill that gap. The authors develop a view of competitive strategy using the rationales of the economics of property rights and transaction costs. The property rights perspective in the theory of the firm sees transaction costs as the costs of capturing, protecting, and exchanging such rights (Barzel 1997). However, this approach has not devoted much attention to the role of contracting and expectations in the process of competitive interaction (Williamson 1999). Foss & Foss (2002) try to overcome this problem by developing a single framework within which the processes of creation, capture and protection of value is encapsulated. Within their framework strategizing encompasses the influence over value creation to the advantage of the firm. As a result, competitive advantage[84] is achieved. Central to the property rights-based view of strategy (PRV) is the fact that all parties engage in capture and protection activities. In addition, contracting plays an important role in strategizing because of its impact on capture and protection activities due to transaction costs that may dissipate the value created. Finally, the PRV accounts for inefficiencies caused by property rights

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[83] See Ernst (1998a) for an example of how analysis of information in patent portfolios can be used in R&D planning.

not being completely secure, and thus one may influence the value she/he appropriates by interfering in others' expectations. In a patent context, this is done by influencing the access of rivals to a technological domain, either directly (e.g., enforcing property rights) or indirectly (e.g., disclosing information that can be used by other agents). And at the same time being influenced by expectations as to the resources other agents will spend on the capture of the value of knowledge created by the patent holder.

Although we have emphasized the role of patents in the appropriation process, it is widely known that patent protection may not be very effective in reaping the economic benefits from innovation. For example, an innovation, even if patented, can be imitated; or the legal system of the country where a patent is obtained may not be favourable to enforcing of property rights. Anand & Galetovic (2004) show some strategies that may work when property rights are weak. In essence, they show that in the absence of strong IPRs a firm may i) threaten offenders with strong competition, ii) exploit complementarities and offer potential offenders a better deal than the contingencies they envisage, and iii) strengthen its position in terms of complementary assets/ products. Therefore, if on the one hand there is a strategic role for patents, on the other hand this role can be constrained.

Thus, the extent that effort and time should be devoted to patent issues is expected to vary. Firms operating in more technology-based sectors are likely to

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[84] Above-normal profits.

be more concerned about appropriability conditions, which may in fact be paramount for the economic success of their R&D laboratories (Brockhoff 2003). Conversely, firms operating in less R&D-intensive sectors may not value patents as much; reputation as well as know-how is perceived more important than patents as a source of sustainable competitive advantage (Hall 1993). Firms should understand the environment in which they operate before committing too many resources to patenting, and if resources are to be used in patent activities, firms should be aware of the purpose, which may not be mere protection (Teece 2000), and of the costs that may dissipate value (Foss & Foss 2002). Thus, two questions that arise are i) whether value can in fact be derived from patent activity, and, if so, ii) how patents are used to create such value. These issues are addressed in the next section where factual data of various kinds are explored for this purpose. Gaps are identified and a research agenda is built upon them. As we shall see our current knowledge on the way patents are used has limitations that justify our interest in carrying out this empirical research.

2.4 PATENTS AND FIRMS: A REVIEW OF EMPIRICAL STUDIES

2.4.1 *THE VALUE OF PATENTS: A SUMMARY*

One of the elements of concern to the strategic management literature is how firms build and sustain competitive advantage, that is, how firms' strategies influence value creation to their advantage. It has been recognised by that literature that there exist forces which limit the extent to which competitive advantage can be duplicated. These forces are known as isolating mechanisms and serve as barrier to imitation. Patents as well as trademarks are types of legal barriers (contracts in many cases can also been seen in this way) that may help firms in achieving that purpose. Thus, patents seem to have a strategic value. The extent of this value, however, is still unclear.

The economics literature is perhaps the literature which has devoted more attention to the evaluation of patents[85]. The value of protection is the difference between patent protection and the next best appropriation alternative (Lanjouw 1993). So, the value of a patent is found in its ability to exclude others from appropriating economic benefits from the underlying invention. But even if a patent is very effective as a barrier to imitation for a particular invention, the corresponding invention may have little or no market value, and hence the economic value of its patent would be only marginal. Thus, the private economic value of a patent depends on both the market value of the invention and the relative strength of the patent protection.

Economists' interest in the value of patents, however, was not initially motivated by the value of patents *per se* but rather by how the impact of technical change on productivity growth could be measured. These studies used to interpret technology as a residual from a production function (Solow 1957). Residuals, however, are not very convincing when something important has to be shown. That certainly left economists in an uncomfortable position and new forms of measurement were pursued (Griliches 1995, 1989). The

[85] See also Lev (2001), and Contractor (2000).

production function model was the point of departure in this body of empirical work. That function connected some measure of output to inputs, and technical knowledge was also incorporated as one of the inputs (Griliches 1979). More specifically, the theoretical framework of the majority of studies is the Cobb-Douglas production function (Griliches 1986), which is presented in logarithms as

$$\log(Y)=a+\lambda t+\alpha\log(K)+\beta\log(L)+\gamma\log(C)+\varepsilon$$

where Y is a measure of output (production or sales), L a measure of labour input and t a trend variable. K and C are measures of the cumulated research effort (capital) and other physical capital, i.e. machinery, buildings etc. λ, α, β, and γ are the unknown parameters to be estimated. The error term (also known as the Solow residual), ε, captures the total factor productivity.

The limited (or non) availability of data on R&D expenditures led some researchers to seek *proxies* to overcome this problem (e.g., Schmookler 1954), and patents were one of them. Why patents? As observed by Griliches (1990:1669) "a patent does represent a minimal quantum of invention that has passed both the scrutiny of the patent office as to its novelty and the test of the investment effort and resources by the inventor and his organization into the development of this product or idea, indicating thereby the presence of a non-negligible expectation as to its ultimate utility and marketability". But the use of patents in productivity measurement has lots of problems associated with it. One of them is that patents disclose information that can be used by other economic agents. Thus, patents are not only outputs of inventive activities but also inputs to these activities. This problem motivated researchers (e.g., Scherer 1965) to look for correlations between patent counts and other variables (e.g., R&D)[86]. Jaffe (1986), for instance, found that a higher ratio of patents per R&D outlay takes place in sectors where firms spend more on R&D, and that the returns to R&D depend on the amount of R&D spent *vis-à-vis* other firms. So, higher returns are achieved if a firm has relatively high R&D expenses whereas other firms in the same industry also have high R&D expenses. Low returns can be expected if a firm invests less in R&D than its industry counterparts.

Difficulties in evaluating the private returns to innovative activity by the above approach made some researchers turn to an alternative method, namely the valuation placed by the financial markets on a firm's assets. Then, again, there are restrictions with this approach, such as its limited applicability because it can be used only for private firms traded on well-functioning markets (Hall 2000). Broadly speaking, this approach has attempted to find a correlation between a firm's intangible assets (with patents and R&D playing an important role as indicators of those assets) and its market value[87].

The market valuation of patents has been addressed using techniques such as correlation analysis (e.g., Ernst 1998b), econometric based models (e.g., Guellec & van Pottelsberghe 2000), or by an option pricing approach (e.g., Pakes 1986). However, for most studies the basis of the analytical framework is the

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[86] This approach is not problem-free either. A more detailed list of problems with this approach can be found in Hall (2000), and Griliches (1990).

Tobin's q approach, which relies on the fact that publicly traded firms are bundles of assets and the market value (the value of equity plus debt) of the firm is related to its stocks of tangible and intangible assets (Tobin 1969). This can be represented as follows:

$$V(A_1, A_2, \ldots) = f(A_1, A_2, \ldots),$$

where f is an unknown function that describes the relationship between the assets.

The function f has been specified in two different ways in the literature: (i) an additive separable linear form, and (ii) a multiplicative separable form. The additive form implies that it would be possible to disentangle the assets and sell them separately for the same price as if they were embedded in the firm. However, when one takes into account intangible assets it is rather difficult to separate them and sell them off. Despite that the additive model has the advantage of simplicity. It also assumes that the marginal shadow value (the gross rate of return) of the assets is equalised across firms. According to Hall (2000), such an assumption is more defensible from a theoretical point of view than the assumption of constant elasticity that underlies the multiplicative form.

The additive model is reliant on Griliches' seminal work (Griliches 1981), which underpinned a number of studies of this sort, and it is given by

[87] See for example Hall (2000), Deng et al. (1999), Pakes (1985), and Griliches (1981).

$$V_{it} = q_t (A_{it}+\gamma_t K_{it})^{\sigma_t} ,$$

where q_t is the discount of market value over the replacement cost of tangible assets of firm i and A_{it} represents the book value of the physical assets of firm i in time t. K_{it} denotes the firm's intangible assets, γ_t measures the shadow value of such assets, and σ_t indicates departures from constant returns and market equilibrium. Taking logarithms of both sides the previous equation becomes

$$\log V_{it} = \log q_t + \sigma_t \log A_{it} + \sigma_t \log (1 + \gamma_t K_{it}/A_{it}).$$

The assumption of constant returns ($\sigma_t = 1$) entails that the equation assumes the form

$$\log V_{it}/A_{it} = \log q_t + \log (1 + \gamma_t K_{it}/A_{it})$$

This framework has produced a body of empirical work. For example, Hall (1993a, b) investigated the stock market valuation of R&D investments in US manufacturing over two decades (1970-1990). She found that the rate of return to industrial research and development fell during the 1980's.

Griliches et al. (1991) observed that information about changes in patenting rates does not provide any additional information beyond what R&D already contains because patenting rates account for only a very small fraction of changes in the stock market value of the firm. But according to the authors this could be because of the metrics employed (patent counts). This was not totally unexpected since Griliches (1981) also found 'surprising' effects in his work. However, a study by Megna & Klock (1993) on the semiconductor industry suggests that R&D stock and patent stock measure different elements of intangible capital. This could be a market structure effect but according to Hirschey (1985) there is no consistent link between market structure and market value. A result that does not reconcile with the research by Blundell et al. (1999), who found that the market values innovations more highly in firms with high market shares than in firms with small market shares. These differences in the results could be because the authors took a different approach and employed innovation counts and market share as measures of innovativeness as opposed to R&D and patent counts.

Stoneman & Bosworth (1994) found that R&D plays a more dominant role than patents in the explanation of market value of UK firms. In contrast, an analysis of the UK pharmaceutical sector by Bosworth & Mahdian (1999) identified that R&D and patents perform broadly the same role in the explanation of market value. Toivanen et al. (2002) observed that equity markets value R&D, but the market value is most sensitive to the first announcement of R&D expenditure in the firm's accounts. The question, perhaps, is whether R&D and patents capture the same effects.

Bosworth et al. (2000) studied the contribution of intangible assets to the performance of 146 UK firms. In addition to patents, their models also accounted for trademarks. Their initial findings indicated that the stock of measured intangibles fails to explain variations in market values, that is, intangible assets did not seem to have a significant influence on firm performance. So, it seemed that the market considered only a few firms to be capable of generating returns to their intangible assets. Nevertheless, there is evidence of systematic differences in the performance of firms that are captured by the firm fixed effects and not by the measured variables. Their further analysis revealed that the variation in firm-specific effects, and thus the variation in the firms' q ratio, is positively related to both the average stock of trademark applications and the average stock of patent publications. Therefore, the value of firm-specific factors is linked to the firm's accumulated patenting and trade mark portfolio.

Schankerman & Pakes (1986) detected that the distribution of the private value of patent rights is sharply skewed. That is, the economic significance of individual patents is variable, with only a very few highly valuable patents. So, when the patent stock is used in empirical analyses, unimportant patents may overshadow valuable patents. Griliches et al. (1991) observed that patents are a noisy measure of the underlying economic value of the innovations with which they are associated. Their findings corroborate the notion that only a few patents are valuable; most of them are of marginal value. Harhoff et al. (2003, 1999) surveyed patent owners in Germany about the value of their patented innovations. They confirmed the existing knowledge that the value distribution of patents is highly skewed.

Austin (1993) was encouraged to undertake analysis at a more disaggregated level as a result of concerns about what makes few patents more valuable than most patents. He drew attention to the relationship between the scope of patents and their market value. However, he found no (statistically) significant evidence that broader patents are more valuable than narrow patents. Using a more disaggregate measure of patent scope, namely the IPC[88], Lerner (1994) identified a positive relationship between scope and market value for biotech companies.

Another approach has been the use of patent citations[89] as a *proxy* for the 'quality of a patent' (Hall et al. 2000). That is, it is assumed that the most valuable patents are those which are most frequently cited by other patents, a hypothesis confirmed by Harhoff et al. (1999). Deng et al. (1999) found that building upon this patent attribute can be a useful tool for the investment analysis of technology- and science-based firms.

Other patent attributes such as i) patent renewals (Pakes & Simpson 1989), ii) family size (Guellec & van Pottelsberghe 2000), iii) oppositions[90] to patent grants (Graham et al. 2003; Harhoff et al. 2003), iv) litigation (Crampes & Langinier 2002), v) accelerated examination requests (Reitzig 2004a), vi) qualified word counts (ibid.), and vii) a composite 'quality index' (Lanjouw & Schankerman 1999) have also been used. Thus, it seems that individual valuation of patents largely depends on their attributes. But this is not the full

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[88] The International Patent Classification (IPC) is a categorization of technology fields suggested by the World Intellectual Property Organization (WIPO) under which individual patent applications are ascribed during their prosecution within patent offices. A patent can end up with several classifications depending on the scope (or breadth) of the invention. They are periodically revised, and countries may have their own classification (e.g., US) but the purpose of the IPC is to standardize the classification across countries. A rough proxy for the scope of a patent (as used by Lerner 1994) is the number of subclasses into which a patent is assigned during its prosecution in a patent office.

[89] Either forward citation (Trajtenberg 1990) or backward citation (Narin et al. 1997).

story; firms' behaviour (Reitzig 2004b), and sectoral differences (Greenhalgh & Rogers 2004) also have a role to play.

Although valuation of patents *per se* is an important issue, we should not neglect *ex-ante* reasons why certain patents are more valuable than others. In this respect, the investigation followed in this thesis of how firms produce their patent portfolios and what attributes firms do possess that make them place more (or less) importance on patents is a step forward toward understanding how the value of patents is created.

2.4.2 *Propensities to Patent*

As there are conditions governing the granting of patents[91], one cannot expect that all firms are able to secure property rights. Moreover, although it is intuitive that firms that hold more patents are more innovative, this can be misleading. It is misleading because it does not account for the effects of, for example, the industry's competitive structure (Comanor 1967), or their size (Scherer 1965). Thus, it is fair to say that the interest in firms' propensities to patent emerged largely due to deficiencies that patents *per se* have as indicators of innovative activity. This line of research has attempted to detect the characteristics of firms that make them more inclined to apply for patents rather than using raw patent numbers to measure firms' level of innovativeness[92].

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[90] Generally speaking, it is a post-grant challenge available to parties that enable them to contest the validity of patents issued by Patent Offices.

[91] The basic premise is that a firm has to have an invention that meets patentability criteria.

[92] See for example the studies by Schmookler (1962a, 1954) where patents are used for that purpose.

There are two main definitions of what is meant by propensity to patent[93]. The first, to the best of our knowledge, dates back to Scherer in 1965. Scherer (1983, 1965) measures propensity to patent as the number of patents per unit of R&D input. His definition may be valuable if one takes into account the availability of such statistics publicly. Nevertheless, Scherer's definition does not allow for possible 'interferences' in the patents-R&D relationship, such as i) the efficiency of R&D, ii) the reasons why firms patent, iii) technological opportunities, and iv) the possible undercounted R&D in small firms. Scherer also used the number of patents as a response variable in estimation models in order to investigate what determines a firm's propensity to patent. This practice seems to have been used more often recently due to advances in the econometrics of count data (e.g., Gourieroux et al. 1984a, b; Hausman et al. 1984).

The second main definition of a firm's propensity to patent is based upon the proportion of inventions/innovations that are patented. The first attempt to use this definition was made by Mansfield (1986) who asked US firms the proportion of their patentable inventions that were patented. Mansfield's definition has the merit of avoiding the R&D productivity problem but has the disadvantage of underestimating the value of patents because many inventions do not necessarily become innovations and therefore have little or no economic consequence. In an attempt to overcome this problem many variants of this

[93] Arundel & Kabla (1998) revise a broader scope of definitions.

definition have been used recently (e.g., Cohen et al. 2000; Duguet & Kabla 2000; Brouwer & Kleinknecht 1999; Arundel & Kabla 1998).

The results derived from previous studies on the propensity to patent agree to a certain degree around particular issues. For example, firm size seems to play an important role in determining the number of patents (Brouwer & Kleinknecht 1999; Scherer 1983, 1965). R&D outlays are also seen as a major factor in determining a higher propensity to patent (Duguet & Kabla 2000; Scherer 1983, 1965). Another point to make is that in industries where R&D expenses are to a large extent government-oriented the propensity to patent is low (Scherer 1983). This result may arise from either the presence of well-established firms whose future market position is not particularly dependent on taking out a lot of patents (Griliches 1990); or because the government supports some industries and insists upon either title or a royalty-free license to any inventions made under its contracts (Scherer 1983); or the level of uncertainty attached to R&D is very high (Taylor & Silberston 1973). But within particular industries that receive government support, the propensity to patent may be high due to the supplementation of the invention-generating potential of company-financed R&D (Scherer 1983). The impact of other forms of support, in particular innovation-oriented collaborations, may also increase firms' propensities to patent (Brouwer & Kleinknecht 1999).

Firms' propensities to patent also vary across industrial sectors. Empirical evidence suggests that differences in technological opportunities are thought to be a major determinant of that variability. Moreover, incentives peculiar to individual industries, such as the relevance of patents to different sectors, may help in determining different propensities to patent (Brouwer & Kleinknecht 1999; Scherer 1983, 1965). Market power, however, seems to have only a modest positive effect on the number of patents (Duguet & Kabla 2000; Scherer 1983), though its intensity may vary by country. A higher degree of competition is conducive to a higher propensity to patent (Arundel & Kabla 1998). Firms with overseas sales also tend to obtain more patents than those with domestic operations only (Scherer 1983).

Another possible explanation for differences in the propensity to patent lies in environmental factors not related to firm and market structures. These factors constitute what Teece (1986) coined 'regimes of appropriability'. These regimes derive, in particular, from the nature of technology and the efficacy of legal mechanisms. By nature of technology Teece means whether it is product or process oriented, and also the extent that the knowledge involved is tacit or codified. By efficacy of legal mechanisms, Teece means the extent that intellectual property rights can be enforced. Regimes of appropriability may not only induce firms to pursue patent protection but also to explain when they are not worth using as a protective device. A tight appropriability regime means that technology is relatively easy to protect whereas a weak appropriability regime means that it is almost impossible to protect a technology.

Nonetheless, one should be cautious when analysing sectoral differences in propensities to patent. It is expected and is, in fact, observed that the likelihood of applying for patents increases with an increase in the perceived importance of patents (Arundel & Kabla 1998). However, even within individual industries one can observe a large variability in firms' propensities to patent (Mansfield 1986). An explanation for this variability is that firms pursue patents for reasons that have nothing to do with protection, as we shall see later in this chapter. Moreover, as Mansfield and associates (1981) observed, the degree of protection is variable. As a result, firms may be more inclined to use other ways of appropriating the knowledge they create. For example, secrecy may be more effective than patents in protecting new processes but less effective in protecting new products (Arundel & Kabla 1998; Levin et al. 1987). This might be a reason to believe that it is hard to attribute sectoral differences in patent propensity rates to process innovations.

However, the effectiveness of ways of appropriating the returns from innovation may change over time. For instance, the perceived effectiveness of secrecy has increased in the US, but apparently this has not happened to patents (Cohen et al. 2000). Even so, Kortum & Lerner (1999) have observed an unprecedented increase in patenting in that country over the past decade. This could be a consequence of institutional changes in US policy or some sort of technological revolution; not least the reduced threshold of inventiveness and the piecework of patent examiners. The authors, however, have found no robust support for these arguments. They suggest that the main cause of such an increase in firms' level of patenting has been changes in the management of innovation. Arundel (2001) suggests that it could be that both patents and secrecy have experienced a rise in their importance but the latter a quicker increase. The author argues that secrecy may compensate for the inadequacies of patents. The evidence from semiconductors by Hall & Ziedonis (2001) is that an increase in the propensity to patent has more to do with changes in the way firms manage the R&D output rather than the R&D input, in particular due to the way in which firms tend to use patents in this industry. A recent study by Hall (2004) seems to support this view to a certain degree because her findings indicate that although R&D has also increased in the electrical and computing sectors, this cannot explain the size of the increase in patenting.

The present thesis, whose roots trace back to Taylor & Silberston in 1973, is not motivated solely by the potential change in firms' patent behaviour, though we suspect that such has possibly occurred as a result of institutional and technological changes as well as globalisation. Although now dated, the path-breaking work by Taylor & Silberston (1973) is still the most comprehensive study of the impact of the patent system on the UK economy. They investigated 44 firms within 5 industries, and their primary concern was with policy issues such as price, UK trade, and administrative costs. We, however, focus on how patents are important and used to strengthen firms' competitiveness in UK manufacturing. Taylor & Silberston (1973) found large variations in firms' propensities to patent, even within the same industrial sector, and also detected a pronounced decline in firms' patent propensity as the size of the line of business increased. Unfortunately they did not have any justification for this behaviour, and more recent studies do not reconcile with it (e.g., Hall & Ziedonis 2001; Scherer 1983). We believe, therefore, this is a good opportunity to revisit the topic.

Furthermore, previous studies have concentrated upon patents applied for or issued. This may not be particularly informative and may overestimate how important is the fundamental attribute of patents, which is stopping others from copying. The potential overvaluation of patents' fundamental attribute rests with the multi-purpose role they play as indicated elsewhere in this thesis (e.g., technology negotiation, researchers' incentive structure, etc.). Although it is expected that those who most apply for patents are those who most value them, they may apply for reasons other than exclusionary ones.

Finally, despite the tradition in the UK as to the use of patents in empirical studies of innovative activity[94] there has not been any specific investigation as to what determines UK manufacturing firms' perception of the importance of patents as a protective device.

It is therefore both of importance and of interest to explore the basic role of the patent system itself (i.e., to incentivise innovation by providing protection against deliberate imitation). This is going to be addressed in this thesis by empirically identifying what makes firms assign more (or less) importance to patents as a mechanism of protection. In providing evidence of what firm attributes are related to the perception of a higher importance for patents as a mechanism of protection we hope to advance our current knowledge as to whether patents are serving their central purpose. Such investigation will be one of the main contributions of this study and differs from existing studies for a number of reasons. Firstly, in looking solely at the exclusionary side of patents, distortions caused by several motivations behind patent applications, reflected in patent numbers, are minimized. Secondly, in identifying the attributes that impact on the perceived importance of patents for protection against copying, based upon data and research method accordingly, we hope to avoid distortions caused by not-controlling for important elements[95] affecting that perception. Finally, the results may help managers, on the basis of their business, assess more clearly whether patents should be pursued.

2.4.3 *Patents and Appropriation*

In order to strengthen competitiveness firms can use isolating mechanisms that are impediments to the imitative dissipation of rents (Rumelt 1987), or analogously, appropriability mechanisms, that are not only forms of precluding replication but also of capturing value from knowledge assets (Teece 1986). But this is no guarantee of gaining competitive advantage because if firms fail to correctly identify the real source of returns they may not protect their resources adequately (Cool et al. 2002). Insofar as patents can be an element of the control of knowledge flows, central to this thesis is the understanding of how patents are used to enhance firms' appropriability process. It is relevant, therefore, to review both the use of patents in relation to other mechanisms of

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[94] Cantwell & Iammarino (2000); Bosworth & Mahdian (1999); Geroski (1991); Patel & Pavitt (1987); Pavitt et al. (1987); Pavitt (1982); Stoneman (1979).

appropriability and how decisions with respect to patenting affect appropriability.

2.4.3.1 *Patents and Other Appropriability Mechanisms*

The underlying reason for our interest in the relationship between patents and other methods of appropriation is that if these other methods were effective means of appropriating the returns from innovation, patents would not be needed. For example, one alternative to increase the benefits derived from the innovative effort is to develop inventions with a degree of complexity that no one else is able to replicate, even if allowed to. Because several bodies of knowledge are required to generate these complex innovations it is possible for the degree of complexity to be such that imitation is either very costly or not economically feasible for late-comers, and hence the complexity itself would bar imitation. Complexity can be a technology-specific characteristic. Even so, innovators may attempt to move across the complexity 'spectrum' in order to achieve non-imitative results. As this may not be economically or technically feasible innovators may need to rely upon other mechanisms. A question that arises is the extent that firms that rely on the complexity of their innovations (or on other methods of appropriation) seek patent protection.

Bekkers et al. (2002) studied the role of patents in shaping the global system for mobile communications (GSM). They found that the market power of the dominant firms in the network was positively associated with their

[95] Industrial sector, for example.

ownership of essential patents. So, even if ownership of IPRs implies restriction of use, which is contrary to standard-setting that aims diffusion of technology, holding property rights over some parts of a complex system may impact on the bargaining power of patent holders and thus may allow a better bargaining position. This suggests that patents and complexity are not substitutes in the appropriation process.

As described elsewhere in this thesis, economic theory has assumed on many occasions that patents and secrecy substitute for one another (e.g., Attalah 2004; Takalo 1998), though a few claim these mechanisms complement each other (e.g., Anton & Yao 2004; Cassiman et al. 2002). Another example regards intellectual property rights. The law itself may pose the reasoning that by having different types of IPRs, covering distinct groups of activities, they substitute for one another because their suitability depends on the output of the intellectual exercise.

Perhaps mirroring theory (or vice-versa) the empirical evidence is still inconclusive as to whether patents and other mechanisms complement or substitute for one another, and this justifies our interest in following this avenue. Although the view that the use of one mechanism excludes the use of another, especially patents, may be on some occasions correct, especially when the analysis is at the innovation-level, this view neglects the possibility that firms develop appropriation strategies. If firms do so, they may use various mechanisms, especially because knowledge can vary in its degree of codifiability, and hence it is important to pay attention to the interaction of mechanisms (if any). Thus, we suspect that firms may use more than one mechanism to compensate for possible limitations of a particular mechanism in appropriating the economic benefits derived from innovative effort.

One of the most revealing studies of firms' perceptions about appropriability is that by Levin et al. (1987). They investigated typical conditions of appropriability in 130 lines of business for US firms. The results of their survey suggest that the efficiency of the patent system is restricted. The authors found that process patents are the least effective mechanism of appropriability amongst those examined. Product patents were rated higher than process patents as a method of appropriability. In turn, secrecy was rated higher than process patents but lower than product patents. Their study also detected that lead-time, the learning curve, and sales or service efforts are regarded as more effective than patents in protecting competitive advantages of new products/ processes. They noticed, however, that in the pharmaceutical industry patents were rated as being more effective than all other means of appropriability. According to the authors this is because the discreteness and easy differentiability of the patentable subject matter of that industry help to develop a comparatively clear standard of assessment of a patent's validity.

The study by Levin et al. (1987) indicates that the studied mechanisms of appropriability could be reduced to two dimensions: i) patents, and ii) other non-intellectual property rights (lead-time, secrecy, learning curve advantages). In an attempt to find patterns in the data the authors carried out factor analysis and cluster analysis of the mechanisms of appropriability. The results of factor analysis, again, suggested that patents and other mechanisms tend not to be used together. However, they recognize that this is not robust evidence since the data did not reduce satisfactorily to these two dimensions. The results from the cluster analysis were not elucidated further. Firms could be gathered into three groups: i) a first group where all mechanisms were not rated effective, ii) a second group where there was a clear distinction between patents and other mechanisms, and finally iii) a third group where all mechanisms were ranked very effective. Although the results are to a certain degree suggestive the significant heterogeneity in the data did not lead to further conclusions.

A similar analysis undertaken by Sattler (2002) for German firms led to the same sort of results. The author detected the existence of one factor where patents and design registration loaded together, and another factor comprising secrecy, complexity of design, long-term employment relationships and lead-time. His cluster analysis results, in line with Levin et al. (1987), suggested that there are three groups, and in one of them all mechanisms are relatively highly rated.

In a follow-up study on mechanisms used to appropriate the returns from innovation Cohen et al. (2000) surveyed 1478 managers in R&D laboratories within US manufacturing industry. They observed, again, that the effectiveness of patents varies across industries, but in the majority of manufacturing industries patents tend to be the least effective mechanism. An interesting result is that secrecy appears to be more heavily employed across industries than was found previously in Levin et al. (1987). Despite being judged of low effectiveness, patents are still applied for as often as they used to be. According to the authors, one reason explaining this finding is that patents add sufficient value at the margin when they are used with other mechanisms.

The study by Cohen et al. (2000) matches to a large degree the findings of Levin et al. (1987). The former found three factors as opposed to the latter where only two factors were detected. One factor accounts for sales, services and manufacturing capabilities, and lead-time. Another factor accounts for patents, and other IPRs. And a final factor contains secrecy. Their results, however, suggest that other IPRs can cross load with the first factor. Moreover, secrecy occasionally loads with patents or complementary capabilities. Therefore, the findings by Cohen et al. (2000) diverge from the substitutability standpoint by pointing that patents and some other mechanisms can be used together.

A somewhat distinct (non-survey based) study is the one by Graham (2003). He investigates the use of submarine[96] patents in the US and concludes that patents and secrecy can be complements. It is advocated that the tacit part of knowledge is better protected by secrecy whilst the codified part better protected by patents (Arora 1997). Although Graham's study does not completely reconcile with the results by Levin et al. (1987) and by Sattler (2002), it parallels the evidence reported by Hounshell & Smith (1988), who described patents and trade secrets being used concurrently by German dye firms.

Moreover, it lends support to the findings of Cohen et al. (2000) with respect to the possibility of patents and secrecy being used together. A recent analysis of the US software industry has extended that possibility from secrecy to other forms of IPRs (Graham & Somaya 2004).

When it comes to patents and lead-time the findings do not converge either. If there is evidence that patents and lead-time do not load together (Sattler 2002; Levin et al. 1987), there is also an indication of the contrary (Cohen et al. 2000). The simultaneous use of patents and lead-time suggests that patents are used not only to protect innovations but also, amongst other things, to slow down competitors. Bresnahan (1985), in studying the plain paper copier market after Xerox's monopoly ended, noticed that this firm "patented every imaginable feature of the copier technology" (ibid:15). Although not being totally clear, first-mover advantages are believed to derive from various sources such as, for example, switching costs, network externalities, and buyer inertia due to uncertainty over quality and/ or due to habit formation (Mueller 1997). On top of that, the durability of first-mover advantages is also a result of the pre-emption of certain scarce assets, such as input factors (e.g., natural resources), geographic and product (i.e., niches for product differentiation) locations, and investments in plant and equipments (Lieberman & Montgomery

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[96] This term refers to patents that make use of continuation patent applications to delay patent grants, and hence to prolong the period that patents applications are kept secret. This practice, however, is no longer possible due to changes in the US patent system.

1988). Thus, patents may suit this type of exercise. This is not to say that neither first-movers always succeed[97] nor that patents are always adequate.

The results of Cohen et al. (2000) could be thought as surprising, since it is argued that the benefits from patents accrued to pioneers are only marginal (Robinson 1988). Perhaps a firm working in a fast track technology area may not consider applying for a patent because at the time a patent is granted the innovation is already obsolete. But a head-start over rivals is not demanded only in areas of fast technological progress. Being a first-mover is not simply an option; first-mover advantage arises endogenously through the combination of capabilities and luck (Lieberman & Montgomery 1998, 1988), and hence may not derive from market structure and the nature of technology. But if patents are used as an entry deterrence mechanism first-movers can benefit more from them (and trade secrets) than can followers (Robinson 1988). However, a head-start may imply that the technology is not completely established (or developed). Thus, perhaps only a small share of the output is patented in the short-run, though this can change over time.

The above suggests that evidence on how patents and other mechanisms of appropriability interact is still sparse. Although previous empirical studies have examined how patents and other appropriation methods interact, their own limitations have not allowed them to move the boundaries of our knowledge much farther, at least with respect to the extent that these methods

[97] See the model by Hoppe (2000) which describes the second-mover as possibly being the most beneficial due to the uncertainty about the profitability of the innovation.

substitute for or complement each other. For instance, a few studies (e.g., Sattler 2002; Cohen et al. 2000; Levin et al. 1987) were not designed for that particular purpose; other studies (e.g., Graham 2003) investigated only two mechanisms (i.e., patents and secrecy); and others (e.g., Graham & Somaya 2004) looked only at one industrial sector (i.e., computer software). Therefore, the interaction between patents and other methods of appropriation is another issue this research addresses. This work is dissimilar from the previous studies not only because different data and analyses are used but also because it encapsulates different mechanisms at the same time across a variety of industrial sectors. As observed from the above, when these mechanisms were studied together the analyses were based on an inappropriate technique, and when the techniques were more sophisticated, the analysis was restricted either to a single industry or to a single mechanism (in addition to patents). We expect that by overcoming some of the limitations of previous studies, we shall make a new contribution.

2.4.3.2 The Role of Patents in Appropriation

Arguing that patents are used to stop imitation is perhaps common knowledge. Empirical studies [98] have reinforced that view, and have extended our knowledge as to why (or not) firms use patents. Those studies have also focused on the limitations of patent protection. Mansfield et al. (1981), for example, detected that holding a patent does not stop rivals completely from entering the market. Patents can be circumvented and, therefore, may not be an effective mechanism to protect innovations.

Those results for the US appear to confirm the UK findings of Taylor & Silberston (1973) which indicate that patents do not provide perfect appropriability as many theoretical models of patenting suggest. Singh et al (1988) also observed that patents are not a priority when UK firms set up their strategies to compete against incumbents and newcomers. Levin et al. (1987) detected that on the top of the possibility of a patent being circumvented, it may not be so effective when subject to stringent legal requirements for proof that it is valid or is being infringed. Moreover, some innovations are difficult to patent. The effectiveness of patents as a method of appropriability thus seems to be limited, it being difficult also to generalize how effective a patent may be.

Mansfield (1986) found in his study of 100 US firms from 12 industries, that there are inter-industry and inter-firms differences on the perception of how useful patents are, and that the incentives patents provide to increase the rate of innovation are very small in most industries studied. Despite that the author found that the bulk of patentable inventions are patented and firms generally prefer to rely on patents than on secrecy. He pointed out some reasons why firms have become more interested in patenting. Firstly, because there has been an increase in perceived competition. Secondly, because there has been a change in firms' product mixes, with more sophisticated product lines, which are more likely to be patented. Finally, because technological paths involving analytical equipment have reached a stage where it is easier for a rival to detect what innovators launch onto the market.

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[98] Levin et al. (1987), for instance.

In addition to the above reasons why firms seek patents, it can be argued that when firms take out a patent they purchase an option (albeit on an asset the value of which is difficult to estimate but that can be defended in due course if necessary) whose cost is not particularly expensive (Geroski 1995). In purchasing this option they are able to prevent duplication and to secure royalty income (Levin et al. 1987). Yet, there is only modest evidence that licensing is extensively used (Arundel & Kabla 1998). Firms may be interested in blocking competitors' attempts to patent closely related inventions, and patents can give some control over a technology path which enables patent holders to settle themselves in a specific market (Cohen et al. 2000). So, the greater the degree to which a firm controls the complementary technologies needed to commercialise an innovation the greater is the incentive to both invest in R&D and apply for patents (Arora et al. 2000). So, patents can be used as assets to trade in technology negotiations (Granstrand 1999).

Moreover, as patents can be used as reasonable indicators of inventive performance it might be expected that they are employed and thus applied for as part of incentive structures for research workers (Geroski 1995), though Duguet & Kabla (2000) found no evidence for this in French manufacturing industry. In addition, firms can use patents to enter foreign markets where licensing to a domestic firm is required (Bertin & Wyatt 1988). Furthermore, the ease with which rivals have information about a firm's development decisions may be an incentive for firms to pursue patent protection (Mansfield 1985). Liebeskind (1997), for example, found out that the use of protective mechanisms (namely rules, compensation schemes, and structural isolation) to keep matters secret is both difficult and costly. Thus, by patenting their inventions firms may increase imitation costs because imitators will need to engineer around the patented invention as opposed to simply imitate it (though this does not mean that imitation is costless).

Despite the usual disclosure required patents do not seem to be very effective in diffusing knowledge. Levin et al. (1987) reported that the use of patent disclosures as a method of learning about competitors' innovation was one of the least effective methods. The firms reported that they relied more on independent R&D and licensing, respectively, to learn about competitor technologies, but in the case of product innovations reverse engineering was the second best alternative. Hall et al. (1988) observed that most UK small-medium sized enterprises (SMEs) do not consider patent information relevant for their business. As innovation requires other technical expertise, such as knowledge about how an equipment operates or how technical information can be used, experimentation is always key for firms to acquire knowledge codified in patent documents (Grubb 1999; WIPO 1997). The private cost of patenting due to knowledge spillovers thus does not seem to be so high. However, one can get more than technical information from a firm's patent portfolio. Patent data enables one to trace patentees' technological trajectory and their technology strength (Ernst 1998a).

The extent to which patents (and the information therein) are used seems to be a result, amongst other things, of country-specific differences in the patent environment. Pitkethly (2001), for instance, observed that Japanese firms use the practice of monitoring competitors based upon patent information more often than UK firms do. And the same applies to US firms as compared to Japanese firms (Cohen et al. 2002). The heterogeneity in firms approach to appropriability is not restricted to the use of patent information. A broad study by Cohen et al. (2002) shows different patterns of use of patents by American and Japanese firms. Pitkethly (2001) also found differences between British and Japanese firms in dealing with licensing of intellectual property rights, where Japanese firms seem to be more prone to take out patents to use in technology negotiations. Granstrand (2000) shows how the organisation of IPRs within Japanese firms has evolved and argues that western firms lag behind. Bertin & Wyatt (1988) also detected different approaches to patenting amongst multinationals. Nevertheless, the usefulness of patents as a protective device for Swiss firms was found not to be very different as compared to US firms (Harabi 1995). Although there are similarities between the US and the UK economies we cannot say in advance that firms in those economies patent for the same reasons, unless we systematically collect evidence to confirm (or not) this view. As our current knowledge on why firms patent relies mainly upon US evidence, and our existing knowledge why UK manufacturing firms patent is poor, this thesis will pursue new evidence on this question.

Although Granstrand (1999) detected patent strategies adopted by multinationals, he did not investigate whether one strategy prevails, or if there are cross-country differences in the way those patent strategies are deployed.

Cohen et al. (2002) have tackled to some extent that issue and addressed a comparison between American and Japanese firms. They have found that Japanese firms hardly ever use the fence strategy; they are keener on negotiating with other players. American firms tend to use patents in their more fundamental aspect: to exclude others; whereas Japanese firms are more inclined to use patents for access and freedom of operation in the market. Although it has changed[99] the Japanese patent system only allowed few claims per patent, which may have created an environment where cross-licensing is more likely to happen than is excludability[100].

The ways and the extent that firms use patents are to a certain degree influenced by the type of industry in which they operate. Bertin & Wyatt (1988) studied the use of patents by multinationals and detected that the existence of an intellectual property strategy is sectoral dependent. In fact, there are industries where the innovation commercialized in the marketplace consists of numerous separately patentable elements ('complex' industries). In other industries ('discrete') only relatively few elements comprise the marketed innovation (Cohen et al. 2000). Cohen et al. (2002) observed that they differ with respect to the purpose patents are applied for. In the case of complex industries firms normally hold patents that other firms need, and vice versa. So, firms become mutually dependent and try to overcome mutual hold-up by cross-licensing and other forms of negotiation and information sharing (e.g., patent

[99] Sakakibara & Branstetter (2001).

[100] See also Granstrand (2000).

pooling). In doing so, they are able to secure their freedom to operate. Hall & Ziedonis (2001) found that firms in the semiconductors industry pursue a strategy of active patenting, which the authors call a 'harvesting strategy' (a combination of flooding and surrounding strategies described earlier). They found that, in semiconductors, patents are largely used in negotiations with other patent holders, so firms are more inclined to patent to avoid hold-ups rather than to enforce exclusivity[101]. This is closely related to the use of patents to avoid litigation initiated by competitors because the length and costs of lawsuits depend on the amount of technical information provided by each party involved (Somaya 2003; Duguet & Kabla 2000).

But a vast patent portfolio is not a 'privilege' of firms in complex industries. Firms in discrete industries may apply for patents on close substitutes to their core invention (Granstrand 1999), though in sectors (e.g., pharmaceuticals) where patents are an effective means of protection firms may not need to build a fence around their core innovations (Cohen et al. 2000). By following this fence strategy firms in discrete industries may end up with a large number of patents, and hence overlapping patents (patent thickets) are likely to be present in these industries as well, even if to a lesser degree than in complex industries. The value of patent thickets, however, seems to be dependent on the use that is made of them (Reitzig 2004b).

[101] See also Grindley & Teece (1997).

Although earlier studies have shed light on firms' patent strategies, our current knowledge is still very thin. We, therefore, take this opportunity to explore which patent strategies firms in UK manufacturing rely on. We expect the findings to add to the current literature. Moreover, although to date the studies have focused on which patent strategies are used, there is no empirical evidence as to the extent that these strategies are used. An analysis of firms' perceptions of the composition of their patent portfolio with respect to the way patents are structured might move the boundaries of our current knowledge forward, and hence this is explored in this thesis.

The empirical literature on patents reviewed above has shown that two major concerns have been addressed: first, why firms do patent (or not), and second, what do they patent (under the format of scope and complements/ substitutes)? Nevertheless, little is known as to other issues concerning the practicality of patenting activity, namely i) where to patent? and ii) when to patent?

Generally, firms should file a patent application in countries where they have or plan to have a business interest. In theory, what is expected is that business strategy identifies either where products will be sold or where growing and likely-to-be-profitable markets are located. Knight (1996) argues that the effectiveness of patent protection, the legal framework and the willingness of firms to spend money on patents should also be considered as factors to be taken into account in deciding where to patent. Grupp & Schmoch (1999) observed that there are in fact several different strategies companies have pursued in the telecom industry regarding the countries where they file patent applications. Guellec & van Pottelsberghe (2000) inferred from their study of small high-tech companies that patenting in a large number of countries may reflect a lack of maturity of the applicant. They argue that, for many technologies, it is enough to combine patenting in the largest markets with economies of scale to get worldwide protection. Nevertheless, few attempts have been undertaken to understand the rationale behind the decision on where UK firms patent. Therefore, this research will fill that gap.

As suggested by Patel & Pavitt (1995) there is not much known as to another issue regarding patent activity, that is, when (in the terms of the innovation timeline) firms choose to make patent applications? Our lack of awareness on that issue clearly justifies our interest in that aspect of the patenting process. Since the regime that governs the vast majority of national patent law is the first-to-file regime it seems logical that patent applications are filed as early as possible (Griliches 1990). Nevertheless, the belief that patent applications are filed at the beginning of the research and development process does not support the idea that patents are able to give adequate protection to inventions, and hence solve the problem of appropriability. Moreover, early applications may incur losses in either how broad or how strong a patent can be since additional information is needed to support what is claimed and this may weaken the validity of the patent and it becomes more likely to be challenged (Knight 1996). Empirically, Pakes (1985) observed a simultaneous relationship between the determinants of R&D expenditures and the determinants of patenting. This indicates that after patents are applied for searches for further uses and improvements of the patented inventions continue, suggesting that patents are applied for at an early stage of the innovation process. However, it is fair to say that our current knowledge as to when (along the innovation process) firms apply for patents resorts mainly to anecdotal evidence. Particularly for pharmaceuticals it is commonly accepted that 'patents are typically granted years before a product completes its clinical testing and is approved for marketing by the regulatory authorities' (Grabowski & Vernon 2000:99). As there has not been a systematic investigation into when firms do apply for patents this empirical research will be the first attempt to do so, and thus will enhance our knowledge on the patenting process.

We have noticed therefore that although the studies above elucidate various patent-related issues, they do not touch on all aspects such as the ways firms' own patent portfolios[102] are 'structured'. What we mean by 'structured' is the composition of the portfolio in terms of patent scope and length resulting from firms' decisions as to why, what, when, and where to patent. We believe, therefore, that this is an opportunity for further research, and it is pursued in this thesis. This piece of research advances our knowledge because it shows how firms' own patent portfolios are produced. To date, existing empirical literature has drawn attention mainly why firms patent. Little is known about the patent portfolio building process. Our current knowledge in this area is to a

[102] What is meant by 'own portfolio' is the portfolio of patents resulted from firms' own innovative effort rather than in partnership with or traded with other organisations.

large extent based upon anecdotal evidence (e.g., Granstrand 1999). There is therefore a need for more integrative approaches.

2.5 A SUMMARY OF THE RESEARCH QUESTIONS

Although there are many studies on the use of patents it seems that there are still gaps in our knowledge, which the above literature review partly reports. It is this vacuum that this research will primarily try to fill by answering three general questions:

i) To whom are patents important?

ii) Do patents complement or substitute for other appropriability mechanisms?

iii) How do firms produce their own patent portfolios?

In order to carry out this work empirically, these general questions are translated into more specific research questions, as follows:

1. What makes firms perceive patents as more (or less) important to protecting the returns from innovation?

2. How do firms' perceptions of the importance of other appropriability mechanisms impact on the decision to patent and on the level of patenting?

3. How do firms act with respect to four basic questions - why to patent?, where to patent?, what to patent?, and when to patent?

The answers to those research questions were pursued on the basis of the research methods described in the next section.

2.6 METHODOLOGICAL ASPECTS: GENERAL REMARKS

The first step towards answering the research questions is to design the procedure that is supposed to provide the answer sought. As Yin (1994:19) observes, "Every type of empirical research has an implicit, if not explicit, research design". In order to outline a research design Punch (1999) argues that a pragmatic approach might be useful, that is, to start by focusing on what is aimed to be found out in the research without engaging fully with the philosophical considerations involved, though he says that a pragmatic choice does not dispense with philosophical issues; they are always present, even if implicitly. For the sake of space we do not deeply engage in philosophical debates but a few remarks are made.

Epistemology is the branch of philosophy concerned with the way knowledge is obtained, or it is about how knowledge is accepted to be valid. One of its stances is positivism, which claims to offer a scientific picture of social events, seeking causes of social phenomena and leaving no room for subjective statements of individuals (Burrell & Morgan 1979). Positivism has four chief principles: i) phenomenalism, ii) nominalism, iii) unity of scientific method, and iv) value freedom (Buckingham & Saunders 2004). Phenomenalism assumes that facts exist prior to research and do not depend on it. Nominalism assumes that although theories guide questions, facts stand independently of them. The unity of scientific method principle claims that all science should accumulate knowledge through direct observation and rigorous testing. The value freedom principle assumes that the collection of facts is different from their evaluation, that is, the facts should not allow for ethical judgements (ibid.).

The weakness of the positivism stance is that there is little space for identifying the meaning of social phenomena. Its strength rests with the possibility of replication and generalisation of the results (Saunders et al. 1997). The present research is based mostly upon the collection of the same information from a sample, which permits replication and generalisation of the results. It is fair to say that the underlying epistemological stance governing this thesis is positivism.

Every research strategy has advantages and disadvantages, and to answer different sorts of questions requires different methods (Punch 1999). Maxwell (1998) asserts that the selection of the research method depends not only on the research questions, but on the actual research situation and what will work most effectively in that situation to give the necessary data. Yin (1994) suggests that a research strategy should be selected according to: i) the type of research question, ii) the control that an investigator has over actual behavioural events, and iii) the focus on contemporary as opposed to historical phenomena. We have selected both qualitative and quantitative methods to tackle the research questions raised throughout this thesis with particular emphasis on the latter.

The research methods were selected during the research design, which consists of an overall plan to guide the research from the collection to the analysis of the data (Punch 1999). The research design is therefore an ordered effort to guide the whole research enquiry. Its development took into consideration factors such as research questions, weaknesses and strengths of research methods, budget and time constraints, and availability of data source. After consideration of the circumstances under which this research project would be undertaken, decisions were taken as to, when applicable, how data would be collected. What is meant by 'when applicable' is that during the research design we came across a data set collected by someone else, that could be helpful in answering the research questions. These supplementary data were gathered by the means of a survey. Our research strategy for data collection was also a survey but, in addition, semi-structured interviews were used to support it. As will become clear the two surveys differ in scope.

After identifying gaps in the literature, and deciding how to collect information to fill these gaps, data collection itself was initiated. The starting point was a series of semi-structured interviews that were expected to provide in depth understanding of relevant issues. They were carried out with the personnel who head the decision-making processes concerned with patents in UK manufacturing firms. We were hoping that this would enlighten us as to issues regarding the decision-making process around patents such that it becomes possible to understand how and why those decisions are made. For such explorations the literature reports a qualitative approach is appropriate (Maxwell 1998). Further, as suggested by Henry (1998), such an approach may provide an orientation or familiarisation with the topic under study. According to Gillham (2000) interviews are useful to obtain information and understanding of issues relevant to the general aims and specific questions of a research project. This part of the research was restricted to firms within the pharmaceuticals industry, because the literature reports that this industry is the one where patents play the most important role, and as such is more likely to yield information that could help us to broaden and deepen our knowledge on the topic. As a result we would be able to better design our own instrument of data collection, and to better interpret factual data gathered from various sources. This was then a purposeful sampling, which is a strategy to select deliberately particular settings, persons, or events for the important information they can provide (Maxwell 1998). Although a purposeful sample such as this has limitations, according to Maxwell (1998) it can be suitable depending on the research goals and the stage the research is at.

On the basis of the results of the interviews the research then progressed to the second phase, a survey. Survey is a research strategy that allows collection of large amounts of data (Fowler 1993), which can be done at a single point in time, also known as cross-section, or repeatedly over a time span, also known as longitudinal (Moser & Kalton 1993). Surveys are used to discover facts about a population and/ or to identify probable causes of behaviour or attitudes (Buckingham & Saunders 2004). Overall, the literature reports that social surveys employ the following methods of gathering data: i) observations, ii) interviews, and iii) correspondence; all of which present advantages and disadvantages (Aldridge & Levine 2001). Observations may be adequate if the researcher can directly observe a phenomenon. If the researcher cannot observe the phenomenon being studied an alternative is the interview (either face-to-face or by telephone). But in general interviews are very time consuming and expensive. Alternatively, postal services can be used, through which the researcher can establish a flow of communication with respondents. The recent IT revolution has opened up other possibilities for the distribution and return of questionnaires, such as the use of floppy disks, emails, and webpages, though little is known about their effectiveness (Salant & Dillman 1994).

Typical disadvantages of mail surveys are that i) it is the method which produces the lowest response rate of the survey methods, ii) there is no opportunity for clarification of questions, iii) encouragement of respondents is very limited, iv) anyone can answer the questionnaire, even if addressed to the most appropriate informant, and v) the accuracy of the information can be influenced because respondents can see all the questions before answering them (Moser & Kalton 1993).

The main advantage of employing mail surveys, as compared to other surveys and research methods, is that it is the cheapest way to gather information if the sample is widely dispersed geographically. Although telephone surveys can also be a cheap alternative, it is only applicable to situations when the informant can be contacted. This however can be particularly unattractive for the researcher because answers are more likely to be formulated based upon the assumption of what the interviewer wants to hear. Furthermore, interviewer voice inflection can influence the response, and respondents are more sensitive to leading questions than are respondents to mail surveys.

An assessment of the various factors pointed out in the literature led to the conclusion that a postal survey should be selected as the leading research technique to collect specific information on patent-related issues ('patent survey'). The target population was all manufacturing firms listed in the Department of Trade and Industry *R&D Scoreboard*. The choice of sample frame was made to be in line with the objectives previously mentioned. Although a list of firms that apply for patents could perhaps be obtained from the UKPO, this would lead to other difficulties such as the lack of information of firms' other attributes (e.g., number of employees). Thus, we used the database above (*R&D Scoreboard*) from which a list of firms could be obtained with additional and relevant information (e.g., R&D expenses, size). We suspect that a sample derived from that database would suffice for the purposes of this study because the literature reports firms that spend on R&D are more likely to apply for patents than are non-R&D spenders, and hence would be able to provide the information of interest for this research. The questionnaire employed was to some extent built upon previous questionnaires elaborated by Pitkethly (2001), Cohen et al. (2000), Granstrand (1999), Levin et al. (1987) and Taylor & Silberston (1973). More detail about this survey is provided in chapter 6.

While awaiting the responses from the above survey data gathered by the UK Community Innovation Survey (CIS) were analysed. The Community Innovation Survey was conducted by the Office for National Statistics on behalf of the Department of Industry and Trade (DTI). The third round of this survey was held in 2001, and the dataset was kindly provided by the DTI for the purposes of this research. The CIS comprises firm-level information for the 1998-2000 period. Our primary concern was with section 15 of the survey which explores the methods of protecting innovations, though responses from other questions were also used in our analysis, as will be clear in the following chapters. A more detailed description of the CIS is found in the Appendix 1. The difference between the CIS and the survey designed by the researcher is the level and detail of information on patents. The CIS was concerned with general innovation-related issues whereas the patent survey addressed more specific questions not present in the CIS, or when present, phrased in a different way.

These three data collection procedures form the bulk of evidence from which our analyses derive. The chapters that follow detail the findings and provide more information both on the way the data were analysed and the research methods used.

CHAPTER 3

BUILDING PATENT PORTFOLIOS: EVIDENCE FROM SIX PHARMACEUTICAL FIRMS

3.1 Introduction

The pharmaceutical industry is perhaps the industry where patents are most valued as a protective device. Although there is evidence that the use of patents may vary across industries, an insight into how pharmaceutical firms make their decisions as to i) why, ii) when, iii) what, and iv) where to patent may thus provide some anecdotal insight.

The exploratory character of this phase of the research demanded an appropriate research method that is described in the next section along with the profile of the sample investigated. The findings are described in the section 3 with some comments on pharmaceutical firms' attitudes towards patenting. The final section of the chapter draws tentative conclusions from the analysis of a limited sample.

3.2 Research Method

As our objective is to understand how firms deal with the patenting process, in particular how decisions are made during that process, we have selected a qualitative method, which has the capability to illustrate processes taking place; processes that experimental and survey research are often poor at identifying (Maxwell 1998). Semi-structured face-to-face interviews were the data collection tools used. They employ a commonality of both themes to be covered and questions to be asked, while, at the same time, providing a flexibility that allows follow-ons to answers when considered useful (Kvale 1996). This technique is also suggested by Gillham (2000) in cases when the research questions require an elaborated in-depth response.

In line with the nature of this type of interview, a series of questions was formulated as a loose guide for reference during the face-to-face meetings (see interview guide in Appendix 2). We also made use of prompts and probes to help the interviewees to provide the information that we were seeking. This is a technique commonly reported in the literature (e.g., Kvale 1996; Foddy 1993) as being helpful to keep focus during the interview. It enables interviewers to have some control over the situation and to steer the direction of the conversation, even if loosely, and thus to cover the required topics. The ultimate objective was to make the interview process to some extent open but not too vague, keeping the flexibility desired without missing the information that was being sought.

The face-to-face interviews were all undertaken with companies in the UK pharmaceutical industry. Although we were aware that there may well be inter-industry differences with respect to patenting activity, we focused on the pharmaceutical industry primarily because the literature[103] reports that this industry is the one where patents are pivotal, at least on the basis of protection from copying. As such we judged that it would be more likely to yield the information we were looking for relating in particular to, what firms patent, why they seek patent protection, when they apply for patents and where they are more likely to register their patent applications. Although these questions

[103] See for example Levin et al. (1987); Mansfield (1986).

apply to all industries, the familiarity of pharmaceutical firms with patent issues is expected to make them more pronounced in that industry than in other industries.

In order to check the suitability of the interview guide and the way the questions were organised a pilot interview was undertaken with the head of intellectual property of a pharmaceutical company originally from another country (Denmark). As Gillham (2000) observes, there is a lot more to interviewing than asking questions. In that sense, a pilot test was useful in providing a first insight into the interviewing process and to help in detecting how to make interviews work. Moreover, it provided us with an understanding of the meaning that particular phenomena and events had for the actors involved.

A requirement for the validity of a research design is that the sample must fit in with other components of the study. So, we followed the recommendations of Miles & Huberman (1994) regarding a qualitative sampling plan. We tried to select our sample as falling into the purposeful sampling category since it could help us to capture to a certain degree a potential heterogeneity among firms in pharmaceuticals (Maxwell 1998). The main criteria for selecting the companies would be their size and their technology - attributes that might impact on the way firms seek patent protection. Nevertheless, as observed by Gillham (2000) in real world research you have to use the methods that are possible. Insofar as access to the interviewees was restricted we ended up with a sample conditioned more by convenience than design. Despite that the final sample (Table 1) seems to have the heterogeneity that was being sought.

Table 1 – Interviewed Firms Profile

Firm	# Employees[a]	# Internal PA[b]	# Patents	Sales[a] (£M)	R&D[a] (£M)
Company A	3,000 - 3,500	03	600	360	57
Company B	100 - 150	Nil	09	7.8	3.0
Company C	50 - 100	Nil	75	1.00	8.6
Company D	100,000+	104	15,000	17,200	2,600
Company E	50,000+	45	10,000	11,400	1,900
Company F	1,000 - 1,500	06	NA	498	106

[a] Source: annual reports.
[b] Patent attorneys.

To generate the sample detailed above we firstly consulted the Department of Trade and Industry *R&D Scoreboard*, for a list of UK pharmaceutical firms undertaking R&D (a total of 54 firms). We randomly selected half of them and obtained correspondence addresses either from the Association of the British Pharmaceutical Industry (ABPI) or over the internet. The names of the individuals who should hold the information we were looking for were obtained either on the internet or by telephone calls to the companies. These were then approached by means of a formal letter explaining the purposes of the research, requesting assistance, and assuring confidentiality in that no source of material would be explicitly named in the research output. We dealt with that stage formally since the process of setting up an interview could indicate to the interviewee how we valued the contribution the interviewees would make (Kvale 1996). We received ten replies of which six, reflecting the heterogeneity we were seeking, acceded to our request. This sample was deemed to be consistent with the aims and objectives of the study and also manageable within the binding time constraints.

Prior to any meeting a checklist of topics that would be addressed was forwarded to the interviewees. On average the interviews lasted 70 minutes each and whenever possible they were tape recorded. The day after each interview, a letter was sent to the interviewee expressing our gratitude for their willingness to help with the research and for being able to set aside a period of time to be interviewed. The recorded interviews were later transcribed. Content analysis was carried out to identify substantive statements made by the interviewees and to group the information in the categories of interest (i.e., why, what, when, and where), for which the interview guide was quite helpful.

3.3 BUILDING PATENT PORTFOLIOS

In this section we review the findings from the semi-structured interviews by looking first at why pharmaceutical firms take out patents and their opinions as to the effectiveness of the patent system; secondly, we report on what firms tend to patent and why; thirdly, we address the timing of patent applications; and finally we analyse where the interviewed firms apply for patents and the determinants of this decision.

3.3.1 *REASONS FOR PATENTING AND THRESHOLD OF PROTECTION*

Many reasons were given for seeking patent protection often confirming what can already be found in the literature (e.g., Bosworth 2005). The primary reason given by the interviewees was the fundamental rationale behind a patent system: to stop others from copying their inventions (for a limited period). The long development time (including clinical trials and regulatory review) and high development costs of a new product in the pharmaceutical industry reinforced the relevance of such protection. In addition, protection was said to be important in pharmaceuticals because such inventions once disclosed are simple to copy. Moreover, we were told that firms are able to easily detect whether another drug infringes the scope of their patents. These properties make patents a useful protective mechanism in this industry.

Patents, by granting exclusivity, help firms to earn premium prices enabling them to more effectively cover the costs of their research (including costs relating to products that do not reach the market). That this is so in the pharmaceutical industry is completely consistent with previous studies (e.g., Levin et al. 1987; Taylor & Silberston 1973). In addition other reasons were given, which we list below.

(i) As an entry deterrent. Firms, especially larger firms, reported that they take out and even hold portfolios of patents in order to undermine the technological development of competitors, delaying, or sometimes even blocking, access to a market niche. Although smaller firms we interviewed also signalled this possibility and interest, they stated that they had insufficient funds to enable them to maintain 'sleeping' patents in force on a regular basis. They have to be more selective when they pay renewal fees. The effectiveness of this approach, however, was said to be variable because rivals may generate knowledge outside the domain of a patented invention. But this approach was said to be, on average, more efficient than relying on just one patent, although it is difficult to generalise.

(ii) To enhance appropriability conditions. Despite the role of patents as entry deterrents we were often told that generally a combination of things is required to enhance firms' appropriation. It was said that firms cannot rely solely on patents and expect that their success will be guaranteed. Overall, in order to reap the benefits from R&D they have to use a broad spectrum of elements that both underpin their sales and avoid other firms to step into their market niches. Although they were not asked to pin point which elements they were talking about sales force, secrecy, and brand (trademarks) were frequently mentioned by the interviewees.

(iii) To secure royalty income. The possibility of out-licensing a technology was definitely taken into consideration by the interviewed firms[104], regardless of their size. Thus, the interviewees felt that they need to have their technology patented in order to out-license it. But, at least on the basis of the emphasis given to this issue by smaller firms as compared to larger ones, it seems that out-licensing may be more important to the former than to the latter. This might be a result of their lack of global production and distribution networks. As such their existence might depend more heavily upon their ability to convince other companies to in-license their technology. Not least, smaller companies may have more problems in covering the costs of clinical

[104] Although we have not identified the conditions under which technology would be out-licensed rather than exploited internally by the firm.

trials, regulatory review and product launch and as such may need to collaborate more often with larger companies. We were informed that if inventions are not well protected by patents it is less likely that larger pharmaceutical companies will in-license them. Although agreements might be made if a patent is still pending, smaller companies reported they tend not to even seek agreements for non-patented inventions. Their limited bargaining power in the absence of patent protection as well as their lack of control of complementary assets were said to put them at a disadvantage in negotiations with larger corporations. If they have an invention that is neither patented nor has a patent pending, they tend not to approach other companies; behaviour reinforced by the problems of maintaining non-disclosure agreements. Larger companies, who tend to operate world-wide, will on occasion consider out-licensing a technology (e.g., to access a particular market) but we were told that even to them, patent protection is a paramount requirement if they want to secure royalty income.

(iv) To use in technology negotiations. Patents, we were told, are used as assets during cross-licensing negotiations. Although cross-licensing was not reported to be key to guarantee freedom to operate for the interviewed firms, as it is, for example, in semi-conductors (Hall & Ziedonis 2001; Grindley & Teece 1997), it is an option that should be kept open, the interviewees said. Our interpretation of the interviewees opinions is basically that patents prove valuable in trading for technologies controlled by others, and thus even if an invention is not of local use, it may be patented in order to be used in acquiring more useful technology elsewhere. On a few occasions, firms said that they engaged in patent pools with other firms.

(v) To influence investors perceptions. By the time of the interviews, all sample firms, but one, were publicly traded in the stock market. Two of them, the smallest ones, indicated that they use patents to give confidence to investors and in turn to facilitate the financing of innovative activities. As further evidence of this, one of the companies in the sample devoted to patent issues almost one third of the content of its prospectus for admission to the official list of the London Stock Exchange. In addition, the prospect of holding a patent may, at least to smaller firms, go beyond funding opportunities because, according to the interviews, financiers may also offer information, advice, and credibility to the investment.

(vi) To signal to others. Following similar lines firms said that in holding patents they signal not only to investors but also to other institutional bodies (e.g, competitors, universities, and so on) who they are and where they may go technologically. The disclosure of their technological competence, although not necessarily in their own interest, may sometimes help in opening windows of opportunities (e.g., licensing, mergers, and acquisitions) of which they are not fully aware. But signalling is not associated only with business opportunities.

It can impact, in at least two ways, on other firms' behaviour. For example, a patented technology may divert other firms R&D direction because in following the same technological path as the already patented technology there are risks that resources will be wasted if a newer technology is not outside of the scope of previous patents. Even if a patent is granted for the newer invention there is also the risk of patent infringement. And in this case, incumbent firms' patent portfolio may signal the likely costs of an infringement.

(vii) To incentivise researchers. We were unable to judge whether patents were effective in this but the companies in the sample considered patents to be at least partly useful as an incentive mechanism. None of the companies, however, reported that patents have a direct relationship with researchers' salaries; behaviour that seems to differ from that found in Japanese companies (Granstrand 2000). For obvious reasons we could not identify whether this is a sectoral difference or a cultural one. According to the interviewees, in the sample firms, patents are only one item amongst many used to measure the performance of human resources (others might include for example publications in academic journals). As there might be areas where it is easier to patent than others it was argued that it may be unfair to use crude number of patents as a performance indicator. In fact, there may be areas where the output of inventive activities will not be patentable at all.

In addition to asking why firms patent we also questioned firms' attitudes to the effectiveness of the patent system. The interviewees, in general, could not envisage that pharmaceutical firms would continue to invest so heavily in R&D if patent protection did not exist. According to the interviews, it seems that the basic premise of the pharmaceutical industry is that in order to get a reasonable return from the investment in R&D a monopoly provided by patents is essential. Nevertheless, although they agreed that the patent system in general is very important[105], the effectiveness of individual patents in protecting property rights was confirmed to be variable.

Patent effectiveness depends upon the extent to which the property rights can be protected by the courts. According to the interviewees, any difficulty in defending a patent in court comes down to: (i) weakness in the patent itself perhaps resulting from limited declared information substantiating its scope, making it liable to be challenged by competitors and/ or; (ii) the legal frameworks in some countries which restrict the extent to which a patent can be enforced. Although the respondents agreed that the litigation process itself is uncertain[106], they complained that the usefulness of patents is somewhat limited in environments where little can be done to overcome infringement. Thereby, the legal system governing the markets in which firms operate considerably affects the effectiveness of patents to those firms.

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[105] The firms also stressed that sometimes patents take too long to be issued which increases the uncertainty of the returns to a particular product.

[106] One of the interviewees even emphasised that patents are tickets to court.

As regards the importance of the subject matter in determining effectiveness, the interviewees reported that due to specificity the core product (drugs) of the pharmaceutical industry is relatively easy to protect from copying. A firm can stop others from copying because copies in pharmaceuticals are easy to detect due to technology and market structure. However, inventors may only be able to block competitors in terms of specific products rather than broad areas of technology in that there might be different ways of doing the same thing, or closely related products ('relatives' as one of the interviewees said) may not be covered by the patent. Often it seems that patents can make things more difficult for, but cannot completely stop, the competition.

It was also indicated to us that there is a cost to obtaining and maintaining patents as well as tackling infringements. In fact we were told that there are cases where infringements may be ignored by patent holders, a particular reason for which (especially for smaller firms) was the relative cost of patent litigation as compared the benefits the enforcement of the patent would bring. This depends to a large extent on the strength of a patent (a mixture of scope, and ease to defend in court) and on how close a patent is to the end of its life. In addition, the costs of taking out and maintaining patents were said to be easily overshadowed by the costs of patent litigation. One of the firms, for example, realised that it would be better off spending money in other activities that could strengthen its competitive position (e.g. R&D, marketing) rather than having equal expenses on patent litigation.

Also, our reporting firms indicated that they tend to keep things secret (either using trade secrets or pure secrecy) regardless of their decision as to the patentability of the invention. But secrecy was said to be more prominent when it is difficult to police the invention (such as new processes or equipment). One of the interviewees also described that there might be situations where know-how is outdated quickly and in such cases it might not be worth seeking patent protection. It seems, therefore, that a combination of patents with other mechanisms is the way firms enhance the degree of appropriability over their innovations.

It was also emphasised that as most pharmaceutical companies operate world-wide, they hold very large numbers of patents (up to as many as one per product per market), and in such circumstances it is only by managing the whole portfolio that they will generate the full benefit of patents and limit, but not necessarily stop, the operations of (potential) competitors.

3.3.2 *WHAT IS PATENTED?*

The interviewees said that their practice is largely to patent new products[107]. A product, however, can take various forms. For instance, it can be a chemical entity, which in general is the active ingredient responsible for fighting against a disease (some of these compounds are not active themselves but are metabolised in the body to form an active drug, they are known as prodrugs); it

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[107] Although product patents are the dominant type the firms also consider process patents and new use patents. The former refers to inventions which describe new ways of manufacturing a product. The latter is a patent related to a substance or a composition which did not have pharmaceutical use previously, or if it had a pharmaceutical use before, it was for different purposes.

can be a composition (a combination of two or more active ingredients, or combination of a pharmaceutical carrier with a compound not used as a drug before), or a drug delivery system (which is a composition that its constituents enable to be administered in a particular way), and so on. Therefore, even if a product patent is the objective, its content may vary from one company to another because the companies operate in different technology fields, have different technical capabilities, and different business interests.

Firms' interests largely lie in product patents because they tend to be the most difficult to invent around, according to the interviews. For example, the ways to manufacture a product may be easier to invent around than the product itself. If competitors develop new processes to manufacture a patented product they will only be able (in the absence of a licence) to market the process itself and not the product. To develop and to market a new competing product other firms will need more resources (financial and time) than simply copying an invention. A product patent will, therefore, delay competition and help in appropriating the returns from invention.

It seems that when 'the product' is a pharmacologically active ingredient the excludability achieved is greater because the patent protects the product however it is made or formulated. The firms stated that if a particular formulation, or a particular process, is patented then others may more easily invent around as compared to inventing around the active ingredient's patent. It was also pointed out to us that the difficulty and resultant high costs associated with the development of new drugs have been increasing the importance of patents relating to drug delivery systems since such inventions may provide more effective ways for an existing drug to be released into the body.

Based on what was reported by the sample studied, it appears that to enhance excludability, firms also attempt to patent not only the technology that leads to the commercialised product but also complementary technologies that may improve a product's performance or its differentiability. In line with the argument of Arora et al. (2000) it seems that the control of complementary technologies is a major incentive to firms to invest in R&D. Our firms said that they are keen on patenting a broad range of inventions encompassing almost anything surrounding a particular product, even if the invention is not within their core business (e.g., machines). However, smaller firms seemed to be more selective because of financial constraints.

Another issue we addressed was the extent to which the scope of a patent helps firms to recoup their investments in R&D. In general, it was indicated that firms seek protection not only for the marketed product itself, but also for as many embodiments of the invention as possible. By securing property rights on the variations of the invention firms are more likely to reach a higher degree of excludability, keeping competitors away not only from the inventor's products but also from very closely related knowledge that may enable competitors to launch a competing alternative in the marketplace. This should facilitate a higher return to R&D. Notwithstanding these arguments, narrow patents are not necessarily to be ignored. On average, they may be of lesser value, and that is why firms seek broader protection, but narrow patents might be applied for more quickly than and as such provide earlier but less extensive protection, which in some cases may prove to be more valuable.

According to the interviewees, if a firm comes up with a breakthrough invention that possibly will serve as a platform technology for others, the benefits of patents are particularly high. As a result companies will attempt to patent not just their own products but the whole field around these products ('blanketing' or 'flooding'). As observed by Granstrand (1999), such an event is most likely when there is an emerging technology which is not close to the prior art. One of the interviewees said that the blocking of a technology field and the 'flooding'/ 'blanketing' phenomena are more likely to happen amongst biotech firms.

3.3.3 *When to Patent? The Timing of Filing Patent Applications*

Figure 1 details a typical route to drug discovery. Briefly, research and development activities may last several years before a product is first launched on the market (perhaps an average of 12 years). The initial phase starts with the identification of targets - the points at which therapeutic agents should intervene in order to fight a disease. Using a high throughput screening search thousands of compounds are tested, and hopefully some compounds (lead compounds) will be able to act on those targets. After the identification of those active compounds, a series of experiments takes place aimed at changing the structure of those compounds in order to optimise their activity (lead optimisation). If that is successful, a candidate drug will go to the longest and most expensive stage: development. We are interested in where in this process patenting is likely to occur.

Figure 1 - Simplified Model of a Route of Drug Discovery

Research Stage		Development Stage
• Target identification • Screening • *Lead identification* • *Lead optimisation*	Drug Candidate	• Scale up • Synthesis • Pharmacokinetics • Clinical trials

A typical response from the interviewees was that firms tend to start to apply for patents as soon as they have a promising compound (*italics* in Figure 1 above). This means that patent applications start to be filed just after the screening phase, (i.e., during lead identification and lead optimisation). At that point, according to the interviews, about 10 - 20% of the total resources necessary to bring a product to the market have been committed. This corroborates the view that patents are applied for at an early stage of the research and development process[108] (e.g., Grabowski & Vernon 2000).

But filing a patent application early means that firms may not have a clear picture of whether or not the final product, the one to be launched onto the market, will be exactly the same as that first identified. On many occasions they do not know even whether the product will be launched because it will not have yet passed through clinical trials. Furthermore, respondents emphasised that R&D is an ongoing process and there are always new results coming out,

[108] It is worth noting that in most other industries the development time of a new product is much shorter than in pharmaceuticals and so patenting may not take place at such an early stage.

which will also be analysed as to their patentability. Thus, even after a patent application is first filed, there might appear new results that are also likely to be patented. Depending on when new results appear they may or may not be incorporated in the first patent application. Firms pointed out that they make use of internal priority whenever possible. That is, they file a first patent application, but within 12 months from the priority date they may file a new application claiming priority over the first one. That occurs if the new outcomes of R&D are deemed to be important enough to be specified in a patent application since those outcomes will enable the applicant to better substantiate what is claimed. As a result, a stronger patent[109] is more likely to be achieved.

They also said that depending on the new results they may decide to apply for other patents within the priority year instead of claiming priority over the first application. That is a judgement based on whether or not the new results will be able to originate a new patent application that does not infringe the first one; and also whether or not it is likely that someone else will file an earlier patent application. When the new output is going to provide only small differences from the first filing and the following filings and/ or when the perceived competition is very high, it is more likely that firms will use internal priority. The continuous character of R&D implies that the boundaries of the invention are likely to be expanded after a first patent application is filed. If new knowledge is also patented, variations (embodiments) of this knowledge can also be protected and perhaps a higher excludability might be achieved.

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[109] A patent that can be stood in court if it is challenged by someone else.

Nevertheless, not all results from further experimentation appear within 12 months of a filing and, therefore, priority over the first patent application cannot necessarily be claimed. The alternative is to file a new patent application. As the new filing embraces other variations of the invention one could expect that it would be deemed to be obvious (no inventive step) by the patent examiner and, therefore, a patent would not be issued on that. It was pointed out to us that if those new results come out before the priority filing is published (at most within 18 months from priority date) the risks of that filing being opposed as to its inventive step are low (not taking into account what someone else is doing). That happens because the former application has not yet been published and therefore the latter does not have to be inventive over something that was not in the public domain. Using one of the respondents' words:

> '*(...) if you file a lot of applications on similar things then you should do it before publication* [of the first filing]. *(...) once it* [the first filing] *is published if you then file them* [follow up applications], *they have to be new and inventive'.*

Firms also said that, although it is not common, they can file more than one patent application at the same time embracing different scopes. According to the respondents this is more likely to happen when the pressure to patent earlier is very high and the information available on the invention is still very limited. So, one can file both narrow and broad patent applications at the same time. Narrow filings rely upon the results obtained up to the time of filing whereas broad filings rely upon inventors' expertise as to the extent that an invention can be broadened in the near future and thus have a more speculative character. If future results come out and are able to support the broader application then one can drop the narrow application and progress the broader one. Likewise, if the results are not enough to support the broader application this can be dropped and the narrower one progressed.

According to the interviews, it seems that the degree of excludability achieved by using patents depends on the extent that several parts of the invention are also patented. Although the nucleus of the invention is the therapeutic agent, if there are various ways to formulate the product, more effective forms of releasing the active ingredient in the organism, or even other uses for the product and these variations are also in a company's patent portfolio, that company has more freedom to operate and more power to block others trying to launch a competing product. For this reason non-product patents (e.g., process and new use patents) may appear, if they do so, later in the drug discovery process (or perhaps even after a product is launched on the market).

Given that patents have a fixed life, the timing of patent applications may considerably affect the time that a product will be protected on the market. If a larger part of the fixed patent term is devoted to further research and development then the period in which protected revenues can be earned will be shorter. This would encourage later rather than earlier application. In order to partially overcome this problem and extend the period of protection, the interviewees said that they may apply for a Supplemental Protection

Certificate[110] (SPC). However, that certificate is limited in scope since it only covers the particular marketed product for which regulatory approval had been obtained.

Follow-up patent applications have a higher risk of being objected to by the patent examiner as to either the novelty or the non-obviousness requirement, and of not being granted because others have filed patent applications in between. However, according to the respondents, later patents derived from follow-up applications may 'extend' the term of protection of the first patent, especially if the applications were made within 18 months of the priority date. As mentioned earlier, such patent applications do not have to be inventive over an application that has not yet been published. As the subsequent applications are supposed to be an 'improved version' of the first filing, they will partially incorporate the subject matter of the first filing plus something new that will enable the patentee to get property rights. Therefore, when a product is launched it is likely that it will also have incorporated these improvements. Thus, when a patent based on the first filing expires the follow-up patents will be still in force. The company, therefore, can achieve a slightly 'longer' patent life (up to 18 months) yielding greater financial returns.

In the meantime if a competitor comes up with an invention based upon the first filing it is likely to infringe any of the follow-up patents. But even if the

[110] This is a certificate issued by members of the European Economic Area (i.e. EU plus Iceland, Liechtenstein, and Norway), which extends for up to five years the term of protection over an invention which has to undergo an administrative authorisation procedure required by law before it is put on the market.

competing innovation does not infringe the follow-up patents, the impact on the leader's sales may not be significant if the latter has property rights over variants of the innovation, which is more likely to happen if follow-up applications are also filed. However, this depends on the scope of the original patent, which can be broad enough to incorporate several nuances of the invention, and for which follow-ups may not be applied for.

3.3.4 *WHERE TO PATENT?*

Regardless of size, all the sample firms had international visions. No sample company applies for patents only to the UK Patent Office, though for some inventions this happens when the firm wants a speedy granting for some particular reason. Even smaller companies, which are more likely to face resource constraints, view patents in an international context. Although such firms have operational bases restricted to the UK, they aim to out-license their technology to larger pharmaceutical companies implying that the resulting products will ultimately be marketed world-wide and, therefore, patent protection is necessary in most of the main international markets.

There was a common response among the sample firms studied as to where patents should be secured. All six companies agreed that the US, Europe (Western) and Japan are the major territories where they should seek patent protection. The chief reason pointed out by the informants was that these countries are the largest markets for pharmaceuticals. The interest in these markets does not mean that the firms studied do not apply for patents in other territories. According to the interviewees, depending on the perceived impact of the invention on their businesses, they can go beyond these major markets. In general, what they reported was that they have a pre-determined list of countries where patent applications are likely to be filed.

Another factor affecting the choice of the country where patent protection is sought is the extent that firms can enforce their property rights. Again, US, Western Europe and Japan are cited as examples of places where legal frameworks are consistent and have the appropriate expertise in case of litigation. Moreover, according to the interviewees, patent office personnel in these territories are more skilful in dealing with patent issues and with operational procedures.

When firms decide that a patent application will be filed it also has to decide whether or not the invention will be filed locally first before it is filed in other countries. We were told that the patent applications of a UK company, for example, will not always be filed first in the UK. Some of the firms have R&D units abroad and they need to follow local rules, that demand inventions created in their territories to be filed first there before anywhere else.

Regarding the decision to patent abroad the favourite route according to the respondents is through the Patent Co-operation Treaty; though attention was also drawn to the European Patent Office (EPO) and to the Paris Convention. When firms choose to go straight to other countries' patent offices, as opposed to the PCT, firms reported that they need to pay attention to whether or not the country is a signatory of the Paris Convention. If so, they tend to use perhaps the most practical aspect of the Paris Convention which is the possibility of claiming priority for applications made in another territory within 12 months from priority date[111]. If the country is not a 'Convention country', the firms aim to make sure that the invention will not be publicly disclosed after the first filing and are more likely to rush to file in that country in order to avoid forfeiting property rights (in particular because someone else may have filed between the date they first filed and the date they filed in a country that is not a signatory of the Paris Convention).

If the interest is just in the European market firms are more likely to use the European Patent Office (EPO) route. However, if the markets targeted do not justify the costs of this route (economies of scale may not apply), they may go straight to the respective patent offices. The PCT route is considered when there are markets of interest which are not covered by the EPO, and most of the time that is the usual route that firms follow. As costs increase the greater the number of countries a firm applies to, the PCT may be of great advantage since it might be cheaper than filing in each of the target countries (as with the EPO route it all depends on the number of countries designated). Thus, matching what theory says (e.g., WIPO 1997), the main advantages of the PCT were considered to be: firms can delay the bulk of the costs which arise when the application goes to the national phase; firms can have a better idea of the invention before they incur these costs; and firms have both a search and a

[111] The date upon which either a patent application is filed (in first-to-file regimes) or an invention is conceived (in first-to-invent regimes).

preliminary examination report that gives a fair idea of the patentability of the invention before the costs of the national phase, which may reduce uncertainty relating to the level of protection.

The timeline of patent filings seems also to be influenced by where firms apply for a patent since the excludability sought may be drastically affected. In deciding where to register their patents, the proprietary position sought may be important. To patent everywhere may seem the best way to get a broader proprietary position. However, as not all patents are of high commercial importance the costs of the patenting process may not justify the benefits of the protection achieved, and a difficult balance needs to be struck between costs and coverage. Thus, it seems that the choice of where to secure property rights is to a large extent dependent on the size of the market, the legal framework, the perceived importance of the invention for the business, and, the costs associated with that.

3.4 CONCLUSIONS

In this chapter we have explored why, for what, where and when UK pharmaceutical firms take out patents. The results arise from a series of interviews with appropriate personnel in six various sized firms, and although it might be difficult to generalise we have no reason to believe that the views expressed are not typical of the pharmaceutical industry, though they may not be typical of all manufacturing industry.

These interviews revealed that although the main purpose of patents is to limit copying (and the effectiveness of patents in this appears to be determined largely by the enforcement climate and the ability of others to 'invent around' a discovery), there are, as expected, a number of additional reasons for firms to apply for patents. Although our results match the evidence of earlier studies, we found supplementary information that patents may attract not only venture capital but also intellectual capital in the form of financiers' expertise, at least with respect to smaller firms.

The interviews have also shown that it is mainly by managing a whole portfolio of patents that firms will generate the full benefits of patents and limit the operations of (potential) competitors. The simplistic view that holding a single patent will generate adequate excludability does not fit the facts (although a strategic patent may be rather effective). The portfolio approach is beneficial to the inventor because it enables him/her to secure property rights on several variants of an invention (making inventing around more difficult) as well as on complementary technologies that may improve a product's performance or its differentiability.

Our findings suggest that patent applications across borders are mainly determined by economic issues. Although the protection achieved is largely determined by the legal framework, the timing of application seems to be quite important in determining the scope of the final patent grant and its 'relatives' (if any). The ongoing character of the R&D process as well as uncertainty due to competition require patent applicants to make decisions on filing patents based upon actual results and future contingencies.

Some final reflections seem to be in order. Firstly, the portfolio approach observed by studying a few pharmaceutical firms indicates their concern with substitute and complementary innovations. Thus, it seems rather difficult, at least in pharmaceuticals, to obtain a strategic patent. It is not unsurprising that the market perceives high patent numbers as representing the difficulty of appropriating the benefits of R&D[112]. On the other hand, high patent numbers may reflect the strength of firms' technological base upon which they compete. Thus, a deeper analysis has to be carried out if one is willing to understand what the figures mean.

Secondly, the effective patent life in pharmaceuticals is often claimed to be rather short. The degree to which patent legislation should accommodate this is unclear. If policy makers are keen on taking this issue further, patent breadth, as expected (Matutes et al. 1996), has revealed itself to be an important element of the patent system design that can be used to decrease deadweight loss.

Finally, the empirical analysis of patent races should be very cautious about using crude patent counts. Although dynamic economies of scale ('success breeds success') may take place, patents may be taken out at various points in time for various reasons. For example, the first patent (priority patent)

[112] See Toivanen et al. (2002).

is applied for early in the innovation process so that improvements can be made before the final innovation is commercialized and new patent applications filed; or the 'surrounding' strategy pursued by firms may underscore the possibility of innovations being complements, and thus one may conclude that earlier innovations were motivated by later ones. In total, however, the evidence provided by the six firms is perhaps a rather thin foundation upon which to make general statements, thus a more comprehensive, and representative, sample is needed.

CHAPTER 4

FIRMS' PERCEPTION OF THE IMPORTANCE OF PATENTS: THE CASE OF UK MANUFACTURING

4.1 INTRODUCTION

There have been many attempts to empirically investigate firms' propensities to patent. Most studies look either at the number of patents issued (either total figures or normalized by R&D outlays) or at the proportion of inventions/innovations patented (Hall & Ziedonis 2001; Duguet & Kabla 2000; Brower & Kleinknecht 1999; Arundel & Kabla 1998; Mansfield 1986; Scherer 1983, 1965). In many ways this is both their strength and weakness. The strength is that these studies have the merit of encompassing the multi-purpose role of patents (as evident from the previous chapter). The weakness is that by looking at patent numbers the results may overestimate how important is the fundamental attribute of patents, that is, stopping others from copying.

Therefore, the purpose of this chapter is to investigate more directly the determinants of firms' perception of the importance of patents in UK manufacturing industry. Particular issues to be addressed are: the extent that the importance of patents varies across industrial sectors and by firm size; whether innovativeness and competitiveness impact on firms' perception of the importance of patents; whether innovation co-operation and government support affect the importance of patents for the firms engaged in these activities; and how the importance of patents varies when firms seek a tighter appropriation strategy. Our results derive from an analysis of responses of firms to questions in the third UK Community Innovation Survey (CIS 3), using an ordered logit model framework.

The second section of this chapter presents the hypotheses to be tested. The third section describes the variables used in the regression analysis. The fourth section justifies the econometric framework employed. The fifth section describes the results. The sixth section discusses the findings. Finally, in the seventh section, conclusions are presented.

4.2 HYPOTHESES

The extensive literature on firms' propensities to patent, presented in chapter 2, underlines several relationships between patenting and firms' attributes. In this chapter only a few of the relationships will be examined due to limitations of the data, though we believe they are the key ones in affecting firms' perceptions of the importance of patents. These relationships are examined by testing the following hypotheses:

H1: The more innovative a firm, the more likely it will be to place a higher importance on patents.

H2: The larger a firm, the more likely it will be to place a higher importance on patents.

H3: The higher the level of competition a firm faces, the more likely it will be to place a higher importance on patents[113].

H4: Firms that receive government support are less likely to place a higher importance on patents.

H5: Firms that establish innovation cooperation with universities are more likely to place a higher importance on patents.

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[113] One could posit that if a monopoly firm uses patents as a barrier to entry this hypothesis would be the opposite.

H6: The higher the appropriation intent of a firm, the more likely it will be to place a higher importance on patents.

H7: The importance of patents varies across industrial sectors.

4.3 VARIABLES

The hypotheses above were tested by examining regression-based coefficients of a set of variables (*proxies*) derived from the CIS 3 questionnaire.

Response variable

(i) **Importance of patents**. The second part of question 15 of the CIS 3 questionnaire poses the following question:

> *"During the period 1998-2000, please indicate the importance to your enterprise of the following methods to protect innovations".*

The respondents were given four ordinal categories: not used, low, medium, and high importance. There were eight methods[114] in total, and responses to one of them, namely patents, served as the response variable in the empirical work of this chapter (we assume that assigning 'not used' means that patents had at most marginal importance over the period 1998-2000).

[114] The mechanisms of protection listed on the questionnaire are: registration of design, trademarks, patents, confidentiality agreements, copyright, secrecy, complexity of design, and lead-time advantage on competitors.

(i) **Innovative capacity.** If firms do not innovate they are unlikely to apply for patents, and hence patents would be of no value to them. Conversely, more innovative firms are hypothesised to be more concerned about reaping the returns from their innovative effort, and patents are one of the mechanisms available for this purpose. Thus, hypothesis H1 was tested using *ex-ante* and *ex-post* measures of innovative capacity. The *ex-ante* measures used in different models were R&D expenses, which is a traditional measure of knowledge stock, and percentage of staff holding a scientific/ engineering degree. R&D expenses were used in logarithmic form to linearise the relationship with patents [115], and were also normalized by firm turnover to avoid confounding the effects of the R&D and size variables.

The percentage of firms' staff educated to science and engineering degree level or above was employed to overcome, at least in part, a common criticism of using R&D, that is, smaller firms may under report this cost. In the estimation both variables refer to the year 2000. One can argue that there is a logical lag between innovating and patenting, and hence one would not expect to use contemporaneous values. However, as shown in the literature (Blundell et al. 2002; Hall & Ziedonis 2001; Griliches et al. 1991), the results of using a lagged structure are roughly

[115] In models used in this study log values are commonly employed because they tend to result in a better fit (as measured by the log-likelihood) than the gross values (Liao 1994).

the same as the results with contemporaneous levels of R&D. We believe the same applies to percentages of personnel with scientific degree because on average these variables tend to vary marginally over time, and thus the estimates are unlikely to be too inaccurate in a non-lagged structure.

As an *ex-post* measure of innovative capacity a dummy variable for whether or not a firm introduced a product new to its industry was used. This is a rough guide as to the degree of innovativeness of a firm since it indicates whether the launched product was new not only to the firm. The reason for using this variable is because the *ex-ante* variables above may not portray the commercial potential of the innovation. Although some firms may put more emphasis on innovativeness than others, they may not necessarily succeed in bring the invention into the market. Moreover, patents are said to be applied for at the beginning of the innovation process (Griliches 1990).

(ii) **Firm size.** Size may impact on firms' perceptions of the importance of patents because, amongst other things, larger firms are less constrained by the costs of patenting activity. We use the logarithm[116] of firm turnover as a measure of their size. Again, this variable refers to the year 2000. Unlike other variables, this variable was derived from the Inter-

[116] For the same reason as R&D outlays.

Departmental Business Register (IDBR) records[117]. This was mainly to enlarge our sample by avoiding non-response. Five outliers were identified and they were adjusted using the CIS 3 data set. If level of patenting is a good proxy for the importance of patents we would expect, according to previous studies (Scherer 1983, 1965), that the importance of patents is positively associated with firm size, as stated in hypothesis H2. Note however that Taylor & Silberston (1973) could not find such a relationship in the UK.

(iii) Degree of competition. The degree of competition may impact on the perception of the importance of patents in a number of ways, but the impact is not unambiguous. On the one hand, a higher degree of competition may show the weaknesses patents have in fully protecting inventions. On the other hand, a higher degree of competition may demand the use of entry deterrents such as patents, even if they are not very effective (Levin et al. 1987). Note that a high number of patents in an industry might be associated with a high degree of concentration in that industry. Thus, incumbents would enjoy the benefits of patents as entry deterrents, and the number of newcomers would be only marginal. In that case a higher importance of patents is likely to be related to a low degree of competition and hence hypothesis H3 that the importance of patents is positively associated with the degree of competition could be

[117] The matching (IDBR-CIS) was done by the Department of Trade and Industry. So, that information was available in the original CIS dataset.

the opposite. In our empirical models an indicator variable representing the firm's largest market is used as a *proxy* for the degree of competition, and hence we suspect that H3 is more likely to be observed. That is, we expect firms operating at international/ national level to be in a more competitive environment than those operating at local/regional level. So, we can test, at least in part, hypothesis H3. The reference market was the national one, and other markets were i) local (situated within approximately 50 miles), ii) regional (situated within approximately 100 miles), and iii) international.

(iv) **Government support.** A dummy variable was introduced to control for whether firms received government support for innovation-related activities. The literature advocates that patents may become less important for those firms that receive support from the government, especially financial support. The argument is that governmental support is given in exchange for, at best, a reduced license fee to be charged if other firms become interested in the innovation (Griliches 1990). So, innovators would have limited incentives to pursue patent protection. We aim therefore to test hypothesis H4 that patent importance is negatively related to support from the government.

(v) **University partnerships.** Hypothesis H5 that the importance of patents is positively related to the establishment of innovation partnerships with universities was tested by means of a dummy variable. This variable was employed to control for companies which set up innovation co-operation with universities. Universities can be seen as one of the major sources of technical knowledge (Trajtenberg et al. 1997). Thus, innovations derived from these partnerships are likely to be of higher scientific content, and hence likely to be patentable. Moreover, patents may be used as an incentive mechanism for the researchers involved. Even if university researchers deem scientific papers more valuable than patents, firms engaging in this type of partnership may be more concerned about patenting because of the anticipated interest of university researchers in disclosing the results of the joint-project. If they do so before a patent application is filed firms will forfeit their rights, since the application will not fulfil at least one of the patentability criteria: novelty.

(vi) **Appropriation intent.** Hypothesis H6 was tested using an index of the overall importance of the mechanisms of protection based upon question 15 of the questionnaire. This index is an aggregate of the importance given to mechanisms of appropriability, which is expected to reflect a higher (or lower) concern about appropriability issues. In doing so, we can verify whether the importance of patents is positively correlated to a higher inclination to appropriate the returns from innovation. Hence, the assumption that follows is that the higher the overall score the more a firm seeks to appropriate the returns from its innovation. So, this index, henceforth 'stated appropriation intent index' (or 'SAI index') was built upon all mechanisms, except patents. For each firm the sum of the importance of its appropriation mechanisms was computed. The literature suggests that regimes of appropriability (a mix of technology characteristic and enforcement climate) may be a reason for firms to pursue patents. To avoid to some extent confounding effects of appropriability regimes, our firm-level index was normalized by the average of the corresponding industrial sector. Then, to make it more interpretable on a scale from 0 to 1 we normalized it by the maximum value of our full sample in manufacturing. Algebraically we have:

$$\text{SAI index}_i = \left(\frac{\sum_{l}^{L} x_{il} \times (N_j)}{\sum_{i}^{N_j} \sum_{l}^{L} x_{il} \times \left(\max \frac{\sum_{l}^{L} x_{il} \times (N_j)}{\sum_{i}^{N_j} \sum_{l}^{L} x_{il}} \right)} \right)$$

Where x_{il} is the importance assigned by each firm i to the mechanism of appropriability l, and N_j is the total number of firms of our sample classified in the industry j, according to the UK 92 SIC. We assume that appropriation intent is exogenous, although it may not be correct[118]. Moreover, the variable constructed to measure appropriation intent derives from the same question as the response variable, which is likely to strengthen the relationship between the two, and hence its strength may underestimate the influence of other variables.

(vii) Industrial sector. Innovativeness has long been recognised as dependent on industrial sectors (e.g., Schmookler 1962a, b, 1954). The same applies to patenting activity (Scherer 1965). So, in order to test the hypothesis H7 that the importance of patents varies across industrial sectors we use dummy variables to identify firms in the following industrial sectors: 1) Basic Metals, 2) Chemicals (excluding drugs), 3) Communication equipments, 4) Electrical equipments, 5) Fabricated metals, 6) Food. beverages and tobacco, 7) Glass, clay and ceramics, 8) Machinery (except office), 9) Medical, precision and optical instruments, 10) Motor vehicles, 11) Office and computing equipments, 12) Other manufacturing, 13) Other transport equipments, 14) Pharmaceuticals, 15) Printing and publishing, 16) Refined petroleum products, 17) Rubber and plastic products, 18) Textiles and clothing, and finally 19) Wood and paper. The baseline was the printing and publishing industry, where patents were roughly found to have minor importance.

A base specification model, without accounting for appropriation intent, was initially estimated. Subsequently, an augmented model incorporating appropriation intent was estimated. These exercises aimed to avoid the effects of appropriation intent masking the effects of other variables, since the response variable (i.e., importance of patents) and the appropriation intent variable derive from the same question in the CIS 3 questionnaire. Table 2 shows the descriptive statistics of all variables above.

[118] Reasons for not overcoming this problem are presented later on.

Table 2 - Descriptive Statistics of Variables

Variable	N	Mean	Median	Min	Max
Continuous					
Sales (£'000s)	3440	23591.21	2662.5	0	3447748
R&D (£'000s)	1680	688.92	0	0	323800
Limited continuous					
% Personnel with technical or scientific degree	2814	4.99	1	0	100
SAI index	2715	0.134	0.083	0	1
Dummies					
Novel Product	3440	0.131	0		
Government support	3292	0.118	0		
Innovation Partnerships	3313	0.139	0		
Market (Local=1; Regional=2; National=3 International=4)	3383	2.710	3		

4.4 ECONOMETRIC FRAMEWORK

As observed above, the dependent (or response) variable is not continuous; it comes from a four-point opinion scale. Therefore, the data available for our analysis are proportions of responses to each category determined by firms with certain attributes (e.g., size, industry), and an appropriate approach for such analysis is needed.

It is commonly assumed in the traditional linear regression model that the error term (ε_i) is independent and identically distributed with zero mean and variance σ^2, that is, iid N (0, σ^2). And the response variable should be linearly related to the explanatory variables. The discrete nature of our response variable, however, may demand a model which departs from the simple linear form. We are interested in the probability that a firm with certain attributes will fit in some category of the scale used. As probabilities are bounded between zero and one, a model in a linear form may lead to nonsense probabilities, not to mention that ε_i will be heteroscedastic (Greene 2003). Thus, models that link the probability of an event to a set of factors are needed. According to Agresti (1990:80) a broad class of models was introduced by Nelder & Wedderburn[119] which allows for the relaxation of some assumptions of the conventional linear regression model. This framework is known as Generalized Linear Models (GLMs)[120], and this framework, for example, does not require the response variable to be strictly explained by a set of covariates in a simple linear form. The function that links response and explanatory variables may be distributed as any monotonic differentiable function. And the random variable may not have a Normal distribution. This framework, therefore, has the merit of encompassing models for continuous and categorical (or qualitative) variables within a unified theory (Agresti 1990).

A special case of the framework above is the framework of probability models[121]. This framework serves as the basis of our approach, and allows for models that produce predictions consistent with the underlying theory (Greene 2003). According to Gourieroux (2000), models dealing with qualitative dependent variables date back to the 1940s with initial applications in biology, followed by psychology and sociology. Generally speaking, it starts with the following definition:

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[119] Nelder & Wedderburn (1972).

[120] We refer the reader to Agresti (1990), and, in particular, McCullagh & Nelder (1989) for more information on the subject.

[121] A more detailed treatment of probability models can be found in Gourieroux (2000), and Ben-Akiva & Lerman (1985).

$$\Pr(\text{event } j \text{ occurs}) = \Pr(Y = j) = F(x, \beta) \tag{4.1}$$

The simplest case is when j takes only two values. This leads to models for binary choice. There are also multinomial choice sets, which need some adjustments of the definitions used in binary choice models. In our case models for ordered data are of particular interest[122]; they are also known as ordered polychotomous univariate models. These models assume that the dependent variable y is generated by a latent variable y* whose values are not observed. It is a function of the vector **x**, and of the vector **β** of unknown parameters. It also has a disturbance term which is assumed to be independent and identically distributed, with zero mean and a shared cumulative density function *F* which is known up to a scaling parameter (Gourieroux 2000). This latent variable can be considered random and is defined by:

$$y^* = \mathbf{x}'\boldsymbol{\beta} + \varepsilon \tag{4.2}$$

What we observe is the value of each alternative (y) of the choice set. So, assuming that our first alternative of the choice set is zero (as it is in fact in our case) and the last alternative is *J*, the observed values can be represented as follows:

$$\begin{aligned}
&y = 0 \quad \text{if} \quad y^* \le \alpha_1 \\
&y = 1 \quad \text{if} \quad \alpha_1 < y^* \le \alpha_2 \\
&y = 2 \quad \text{if} \quad \alpha_2 < y^* \le \alpha_3 \\
&\cdot \\
&\cdot \\
&\cdot
\end{aligned}$$

[122] See, for example, Zavoina & McElvey (1975).

$$y = J \quad \text{if} \quad \alpha_J < y^*$$

Where $\alpha_1 < \alpha_2 < ... < \alpha_J$ are the threshold parameters with lower and upper limits $\alpha_0 = -\infty$ and $\alpha_{J+1} = +\infty$, respectively. Then, from the above we can define the following probabilities:

$$\Pr(y = 0 \mid \mathbf{x}) = \Pr(y^* \leq \alpha_1) = \Pr(\varepsilon \leq \alpha_1 - \mathbf{x}'\boldsymbol{\beta}) = F(\alpha_1 - \mathbf{x}'\boldsymbol{\beta}) \tag{4.3}$$

$$\Pr(y = 1 \mid \mathbf{x}) = F(\alpha_2 - \mathbf{x}'\boldsymbol{\beta}) - F(\alpha_1 - \mathbf{x}'\boldsymbol{\beta}) \tag{4.4}$$

$$\vdots$$

$$\Pr(y = J \mid \mathbf{x}) = 1 - F(\alpha_J - \mathbf{x}'\boldsymbol{\beta}) \tag{4.5}$$

To model the probabilities above we need to specify a probability density function *f*(.) that corresponds to the cumulative probability distribution, *F*(.). In other words, a monotonic differentiable function that also allows for the probabilities to be bounded between zero and one is needed, that is, $f(z) \geq 0$ and $\int_{-\infty}^{+\infty} f(z)dz = 1$. The most commonly used functions are i) the normal distribution (probit models), and ii) the logistic distribution (logit models). The former has a choice probability that is expressed as an integral whereas the latter is expressed in a more closed form (Ben-Akiva & Lerman 1985). The analytical convenience of the logistic distribution and its good approximation to the normal distribution are the main reasons for its choice, although it is difficult to justify its choice on theoretical grounds (Greene 2003).

Thus, from (4.3), (4.4), and (4.5) we have the following in the logistic format:

$$\Pr(y=0\,|\,\mathbf{x}) = F(\alpha_1 - \mathbf{x}'\boldsymbol{\beta}) = \Lambda(\alpha_1 - \mathbf{x}'\boldsymbol{\beta}) = \frac{e^{\alpha_1 - \mathbf{x}'\boldsymbol{\beta}}}{1+e^{\alpha_1 - \mathbf{x}'\boldsymbol{\beta}}}$$

$$\Pr(y=1\,|\,\mathbf{x}) = \Lambda(\alpha_2 - \mathbf{x}'\boldsymbol{\beta}) - \Lambda(\alpha_1 - \mathbf{x}'\boldsymbol{\beta}) = \frac{e^{\alpha_2 - \mathbf{x}'\boldsymbol{\beta}}}{1+e^{\alpha_2 - \mathbf{x}'\boldsymbol{\beta}}} - \frac{e^{\alpha_1 - \mathbf{x}'\boldsymbol{\beta}}}{1+e^{\alpha_1 - \mathbf{x}'\boldsymbol{\beta}}}$$

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$$\Pr(y=J\,|\,\mathbf{x}) = 1 - \frac{e^{\alpha_J - \mathbf{x}'\boldsymbol{\beta}}}{1+e^{\alpha_J - \mathbf{x}'\boldsymbol{\beta}}}$$

Therefore, generally speaking we have:

$$\Pr(y=K\,|\,\mathbf{x}) = F(\alpha_K - \mathbf{x}'\boldsymbol{\beta}) - F(\alpha_{K-1} - \mathbf{x}'\boldsymbol{\beta})$$

$$\Pr(y=K\,|\,\mathbf{x}) = \Lambda(\alpha_K - \mathbf{x}'\boldsymbol{\beta}) - \Lambda(\alpha_{K-1} - \mathbf{x}'\boldsymbol{\beta})$$

$$\Pr(y=K\,|\,\mathbf{x}) = \frac{e^{\alpha_K - \mathbf{x}'\boldsymbol{\beta}}}{1+e^{\alpha_K - \mathbf{x}'\boldsymbol{\beta}}} - \frac{e^{\alpha_{K-1} - \mathbf{x}'\boldsymbol{\beta}}}{1+e^{\alpha_{K-1} - \mathbf{x}'\boldsymbol{\beta}}}$$

One can notice from the above that the parameters are not linearly related to the dependent variable since a logistic distribution for the disturbance term was chosen. In other words, we are assuming that the error terms are independent and identically Gumbel (or type I extreme value) distributed (Ben-Akiva & Lerman 1985).

The model is estimated using the principle of maximum likelihood, which provides a means of choosing asymptotically efficient estimators for the parameters. It determines the value(s) of corresponding parameters that would make a sample most probable to happen. The likelihood function can be described as:

$$f(y_{ik}\,|\,\theta) = \prod_{i=1}^{N}\prod_{k=1}^{K} \Pr(y_i = k\,|\,\mathbf{x})^{I(y_i=k)}\text{; or}$$

$$L(\theta)=\prod_{i=1}^{N}\prod_{k=1}^{K}(F(\alpha_K - x_i\beta) - F(\alpha_{K-1} - x_i\beta))^{I(y_i=k)} \quad (4.6)$$

$I(y_i=k)$ takes the value of 1 when $y_i=k$ and zero otherwise. Taking the logarithmic of the likelihood function (4.6), we have:

$$\lambda(\theta)=\sum_{i=1}^{N}\sum_{k=1}^{K} I(y_i = k) Ln\big(F(\alpha_k - \mathbf{x}'\beta) - F(\alpha_{k-1} - \mathbf{x}'\beta)\big) \quad (4.7)$$

Then, the above function is maximized with respect to β, which in general is assumed not to vary across categories. This is called the proportional odds assumption. Nowadays it is possible to computationally relax this assumption and to allow the effects of the explanatory variables to vary with the point at which the categories of the dependent variable are dichotomized. This leads to the generalized ordered logit model.

The interpretation of the estimates is straightforward. A positive sign of a coefficient indicates an increased chance that a subject with a higher score on the corresponding explanatory variable will be observed in a higher category. Hence, a negative coefficient indicates that the chances that a subject with a higher score on the independent variable will be observed in a lower category. Unfortunately this straightforwardness does not apply when measuring the goodness of fit of these models. Unlike ordinary least square regression (OLS), there is no single measure that reflects the proportion of the variance accounted for. A starting point to measure the goodness of fit of this type of model is using the likelihood ratio (LR) test statistic:

$$LR(i) = -2\left[LL(\alpha) - LL(\alpha,\beta)\right] \quad (4.8)$$

The LR statistic is chi-squared distributed with 'i' degrees of freedom and allows one to determine if the overall model is statistically significant. Where 'i' is the number of explanatory variables; $LL(\alpha)$ is the log-likelihood of the model which only has a constant and $LL(\alpha,\beta)$ is the log-likelihood of the model with the explanatory variables. In order to measure goodness of fit a transformation of the likelihood ratio is commonly employed, which is the likelihood ratio index, also known as pseudo-R^2. There exist other possibilities but for our purposes the McFadden's-R^2 will suffice. It is defined as:

$$\text{McFadden's-R}^2 = 1 - \left[LL(\alpha,\beta)/LL(\alpha)\right] \qquad (4.9)$$

This is a scalar measure which varies between zero and 1. Nonetheless, it is important to exercise some caution in dealing with this index. Unlike R^2 in OLS, the likelihood ratio index is not the percentage of the variation in the dependent variable that is 'explained' by the estimated model. It is simply the percentage increase in the log-likelihood function of the zero-parameter function when parameters are introduced to estimate the model. The meaning of such a percentage increase is unclear. Therefore, it has no intuitively interpretable overall meaning, except in its extreme values (Train 2003). It might be valid to say that a model with a higher likelihood ratio index fits the data better. But this is only true if the models were estimated on the same sample and with the same set of alternatives. If we are estimating models with different covariates, but with the same set of alternatives (i.e. the same response variable), the Akaike's Information Criterion (AIC) might be more useful (Akaike 1973). The smaller the value of the AIC, the better the fit of the model to the observed data. The AIC, unlike the Likelihood Ratio Test, has been used to select among non-nested models.

The next section presents the outcome of our regression analysis using ordered logit models. It should be clear from previous discussion that the dataset is a cross-section, and the unit of analysis is the enterprise - henceforth firms. In chapter 1 we mentioned that the term 'firm' would be employed loosely in this thesis but we should not overlook the implications of the level of analysis for the results. Regarding the CIS dataset our analysis is at enterprise level and enterprises are defined as the smallest combination of legal units that produce goods or services, and which benefits from a certain autonomy in decision making, especially for the allocation of its current resources. It might be that quite a few enterprises belong to the same group of companies and the consequences of this for our results are not very clear. For example, if one enterprise is responsible for carrying out R&D for the rest of the group it may be that the remaining enterprises will not report R&D but are likely to report that they hold patents, which could underestimate the impact of R&D on the importance of patents.

4.5 RESULTS

A first look at the importance of patents gives the impression that patents are relatively unimportant in UK manufacturing as compared to other mechanisms (Table 3). Nevertheless, if attention is drawn solely to firms that used mechanisms of appropriability, the importance of patents seems to significantly increase compared to the importance of other mechanisms (Table 4).

Table 3 - The Importance of Appropriability Mechanisms (full sample)

Mechanism	N	mean	sd	min	max
Lead-time	2794	**1.034**	1.193	0	3
Secrecy	2782	**.911**	1.155	0	3
Conf. Agreement	2789	**.903**	1.170	0	3
Complexity Design	2772	**.779**	1.051	0	3
Trademarks	2776	**.683**	1.100	0	3
Patents	2786	**.604**	1.075	0	3
Copyright	2757	**.535**	.978	0	3
Registration Design	2767	**.496**	.962	0	3

It is not unexpected that patents are more important for those who use them than for those who do not use them. But it is somewhat striking that their importance increases by more than, for example, lead-time, trademarks, and complexity of design. It thus seems worth pursuing what factors are likely to impact on the importance firms place on patents.

Table 4 - The Importance of Appropriability Mechanisms (restricted sample - users)

Mechanism	N	mean	sd	min	Max
Conf. Agreement	427	**2.351**	.727	1	3
Secrecy	423	**2.322**	.739	1	3
Patents	420	**2.312**	.791	1	3
Lead-time	434	**2.272**	.766	1	3
Trademarks	413	**2.245**	.776	1	3
Registration Design	401	**2.085**	.792	1	3
Complexity Design	415	**2.055**	.777	1	3
Copyright	403	**2.042**	.817	1	3

The estimation results come from four models, where two different variables for innovative capacity are used, and the incorporation of appropriation intent is made in each case. The purpose of this differentiation in what measures innovative capacity was not a mere sample enlargement due to more responses to the question on the amount of technical staff than to the question of how much R&D was spent. The objective was to identify the impact of non-reporting of R&D on the results. It was expected that firms reporting R&D were, on average, larger than those not reporting R&D since smaller firms may undertake innovative activities in a less structured way, and therefore may not necessarily report this cost. Thus, by relying solely upon R&D as a measure of innovative capacity the results could be affected by sample selection bias.

Table 5 – Estimates of Ordered Logit Models for Patent Importance in UK Manufacturing[a,b]

Expl. Variable	(1)	(2)	(3)	(4)
R&D intensity (Log)	0.181***		0.064	
	(0.070)		(0.074)	
% Sci./Eng. Staff		0.017***		0.005
		(0.005)		(0.005)
Sales (Log)	0.467***	0.421***	0.324***	0.296***
	(0.064)	(0.038)	(0.070)	(0.040)
Novel Product	0.434**	0.972***	0.068	0.298*
	(0.191)	(0.132)	(0.222)	(0.157)
Local market[c]	-0.344	-0.937***	-0.232	-0.635**
	(0.590)	(0.254)	(0.588)	(0.264)
Regional market[c]	-0.348	-0.967***	-0.128	-0.366
	(0.459)	(0.233)	(0.544)	(0.252)
International market[c]	0.124	0.433***	0.108	0.253*
	(0.214)	(0.127)	(0.228)	(0.144)
Gov. Support	-0.269	0.351**	-0.294	0.066
	(0.214)	(0.142)	(0.242)	(0.153)
Univ. Partnerships	0.608**	0.506***	0.943***	0.449**
	(0.250)	(0.189)	(0.305)	(0.226)
SAI index			10.786***	11.143***
			(1.211)	(0.546)
Industry dummies	Yes	Yes	Yes	Yes
N	492	2258	467	2202
Log-Likelihood	-553.0	-1661.8	-443.9	-1222.0
Model Chi-square	113.88***	467.40***	170.42***	691.39***
Pseudo-R^2	0.1044	0.1691	0.2417	0.3586
AIC	2.366	1.498	2.030	1.137

[a] Robust standard errors in parentheses.
[b] * significant at 10%; ** significant at 5%; *** significant at 1%.
[c] The reference market is the national one.

In fact, both the average sales and number of employees of models (1) and (2) in Table 5 were compared. On average, both sales and number of employees are higher for the sample in model (1) than for the sample in model

(2). The estimation results of model (1) come from a sample which presented in 2000 average sales of 50 million pounds and 321 employees. Whereas the results of model (2) derive from a sample with average sales of 20 million pounds and 181 employees in 2000. Another difference across the models in Table 5 is the estimation (or not) of firms' appropriation intent (SAI index) for reasons already put forward when the variables were described.

A clear picture that emerges from the aforementioned results is the larger magnitude of the estimate of the correlation between the importance of patents and firms' appropriation intent, compared to the relationship between patents and other variables in the models. The coefficients for the SAI index in models (3) and (4) can be interpreted as a significant and positive increase in the probability of regarding patents as of high importance as opposed to medium, low or no importance when comparing those who most valued other appropriation mechanisms and those who least valued these mechanisms. Hypothesis H6 that states that the higher the appropriation intent of a firm, the more likely it will be to place a higher importance on patents cannot be rejected.

It is also noticeable that when appropriation intent is incorporated in the models most of the remaining explanatory variables become non-significant, although size and partnership with universities remain significant. The emergence of non-significant (or significant) estimates in models accounting for overall appropriation intent could be a result of multicollinearity when this variable is included. The correlation matrices of these models do not corroborate this view (Appendix 3), as the correlations with other variables are weak. So, that possibility should be discarded. Although we suspect that appropriation intent may capture to a certain degree the effects of other variables, we conjecture that the observed phenomenon is a result of both the response variable and the SAI index being derived from the same survey question.

Size[123] and partnerships with universities have shown some persistence across models. As both variables are significant and positively associated with a higher importance of patents hypotheses H2 (the larger a firm, the more likely it will be to place a higher importance on patents) and H5 (firms that establish innovation cooperation with universities are more likely to place a higher importance on patents) cannot be refuted.

Regarding innovative capacity, models (1) and (2) suggest that it is positively related to the importance of patents, which lends support to hypothesis H1 (i.e., the more innovative a firm, the more likely it will be to place a higher importance on patents). Those models were also estimated replacing the introduction of new products by another variable representing whether or not a firm had introduced a new process to the industry[124]. Again, the importance of patents was detected to be positively associated with a higher degree of innovativeness. However, we should interpret these last results carefully. First, because the variable was not significant when R&D was

[123] These results were not different when firm size was controlled using firms' number of employees.

[124] We attempted to estimate models with variables for both product and process innovations simultaneously but we could not avoid collinearity and hence they were discarded.

controlled for[125]. And second, because being a process innovator does not preclude a firm from being a product innovator. In fact, in our sample half of process innovators are also product innovators[126]. In line with previous studies (e.g., Levin et al. 1987), the perceived importance of patents seem to be smaller to process innovations than to product innovations.

The results from models (3) and (4), however, cast some doubt on hypothesis H1 (the more innovative a firm, the more likely it will be to place a higher importance on patents). That is to say, the effects of appropriation intent seem to prevail over innovativeness effects. It could be that innovative capacity effects have captured appropriation intent effects in models (1) and (2), leading their coefficients to be more pronounced and significant. This might be said to overestimate the impact of innovativeness on the importance of patents. But if innovative capacity coefficients in models (3) and (4) are not significant (or are only marginally significant) it does not necessarily mean that innovative capacity does not positively impact on the importance of patents. As expected, this can be a problem with the metrics involved, namely the origin of the data used to measure appropriation intent. Therefore, the results for innovative capacity can be considered as in line with previous studies as indicating positive impact on the importance of patents. This may be evidence that patents,

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[125] The estimates for the introduction of novel process innovations are the following when we control for R&D and for technical skills, respectively: i) 0.218 (Wald test= 0.91; p-value=0.364), and ii) 0.546 (Wald test=3.43; p-value=0.001).

[126] Of the total number firms in our full sample (N=3440) 271 reported to have implemented a process new to their industry, 137 of which also reported to have introduced new products to the industry. The total number of firms reporting introduction of new products (regardless of whether or not introduced new processes) was 451.

in fact, matter, and the hypothesis that the more innovative a firm, the more likely it will be to place a higher importance on patents (H1) should not be rejected.

Regarding competition, it is noticeable in (model (2)) that patents are judged more important by those operating in more competitive environments. Taking the national market as a point of reference, the likelihood that patents will be regarded highly important as opposed to medium, low or not important decreases for less competitive markets (local and regional) and increases for a more competitive market (international). This, however, does not hold in model (1). This is because the sample in this model comprises on average larger firms, as was described earlier. So, even if the major markets are local and regional, for example, they might be part of a group of companies which has a patent policy dictated by the head office. Another possible explanation for the degree of competition not being significant when R&D is taken into account is that R&D intensity itself may reflect competition. So, effects of competition may be embedded in the R&D variable. These arguments however are unlikely to apply to the proportion of personnel educated in science and engineering, which reinforces that hypothesis H3 (i.e., the higher the level of competition a firm faces, the more likely it will be to place a higher importance on patents) should not be rejected, although appropriation intent may be capturing the effects of competition and at best allowing a modest positive impact of competition on the importance of patents in models (3) and (4).

Contrary to our suspicion as to the negative effect of government support on the importance of patents, the results from Table 5 suggest that government support provides an incentive for the perception of a higher importance of patents when percentage of technical skills is controlled for (model (2)). Although this cannot be said when R&D is taken into account, this difference may have to do with the average firm size of the samples in models (1) and (2). If on the one hand, government may condition its support on the grounds of weaker appropriability due to moral hazard reasons. On the other hand, government has to create proper conditions to underpin innovation activities, and patents are one of the public policy instruments available. These results are for any type of government support for innovation-related activities. In order to explore these results a bit further the models were re-estimated using an explanatory variable to identify whether or not financial support was given, instead of any type of support. The results are pretty much the same, that is, a negative impact but insignificant in the variant of model (1), and positive and significant in the variant of model (2). For the same reason discussed for innovative capacity the non-significance of the estimates when appropriation intent is accounted for should not obscure our analysis. Hypothesis H4 (i.e., firms that receive government support are less likely to place a higher importance on patents), therefore, should be refuted.

Table 6 – Importance of Patents and Number of Patent Applications Across Industrial Sectors (descriptive statistics)

Industry	Importance of patents[a,c]		Number of patent applications[b,c]			
	N	Mean	N	Mean	Min	Max
Basic Metals	60	0.58	64	0.66	0	25
Chemicals, except drugs	85	1.34	92	3.20	0	80
Communication equip.	95	0.95	100	5.30	0	135
Electrical equip.	166	0.81	172	1.79	0	100
Fabricated metal	291	0.34	336	0.30	0	48
Food, beverages and tobacco	211	0.30	225	**0.10**	0	10
Glass, clay and ceramics	71	0.61	79	1.33	0	90
Machinery, except office	210	1.00	229	1.59	0	47
Medical and precision instr.	152	1.03	156	2.31	0	78
Motor vehicles	178	0.82	183	1.14	0	50
Office and computing equip.	40	0.73	45	2.47	0	70
Other manufacturing	365	0.49	394	0.49	0	50
Other transport equip.	112	0.46	120	0.35	0	10
Pharmaceuticals	17	**1.82**	17	**39.12**	0	300
Printing and Publishing	240	**0.17**	266	0.32	0	30
Refined petroleum products	13	0.62	14	0.57	0	5
Rubber and plastic products	141	0.79	142	1.72	0	50
Textiles and clothing	172	0.34	180	0.24	0	10
Wood and paper	167	0.50	174	0.22	0	6

[a] Scale from 0 (no importance) to 3 (high importance).
[b] 1998-2000.
[c] Numbers in bold are column maximum and minimum values.

Evidence from the literature suggests that even within industries where patents are relatively non-important for protection purposes, one can find firms interested in filing many patent applications (Mansfield 1986). In fact, this can be observed in our sample if one looks at the range of patent applications within each industrial sector in Table 6. Yet, on average, industries where patents are regarded more important are also industries where patenting activities are more intense. There are only a few exceptions[127]. Thus, it seems that patent numbers can be a good proxy for the importance of patents. This

[127] For example, firms in the office and computing industry regard patents less important than firms in the electrical equipment industry. However, the former presents a higher average number of patent applications than the latter does.

result contrasts with our initial suspicion that the level of patenting may overstate the importance of patents (for protection purpose).

Table 7 – Importance of Patents Ranked Across Industrial Sectors

Table 6	Table 5			
	(1)	(2)	(3)	(4)
Printing and Publishing	Printing and Publishing	Printing and Publishing	Printing and Publishing	Printing and Publishing
Food, beverages and tobacco	Food, beverages and tobacco	Food, beverages and tobacco	Fabricated metal	Fabricated metal
Fabricated metal	Refined petroleum products	Other transport equip.	Food, beverages and tobacco	Food, beverages and tobacco
Textiles and clothing	Other transport equip.	Refined petroleum products	Textiles and clothing	Textiles and clothing
Other transport equip.	Basic Metals	Textiles and clothing	Refined petroleum products	Other transport equip.
Other manufacturing	Glass, clay and ceramics	Office and computing equip.	Other transport equip.	Other manufacturing
Wood and paper	Wood and paper	Basic Metals	Wood and paper	Wood and paper
Basic Metals	Textiles and clothing	Other manufacturing	Glass, clay and ceramics	Glass, clay and ceramics
Glass, clay and ceramics	Motor vehicles	Glass, clay and ceramics	Other manufacturing	Basic Metals
Refined petroleum products	Chemicals, except drugs	Fabricated metal	Basic Metals	Office and computing equip.
Office and computing equip.	Electrical equip.	Wood and paper	Motor vehicles	Refined petroleum products
Rubber and plastic products	Other manufacturing	Communication equip.	Office and computing equip.	Rubber and plastic products
Electrical equip.	Office and computing equip.	Electrical equip.	Rubber and plastic products	Electrical equip.
Motor vehicles	Communication equip.	Pharmaceuticals	Electrical equip.	Motor vehicles
Communication equip.	Medical and precision instr.	Motor vehicles	Communication equip.	Communication equip.
Machinery, except office	Fabricated metal	Chemicals, except drugs	Machinery, except office	Machinery, except office
Medical and precision instr.	Pharmaceuticals	Medical and precision instr.	Chemicals, except drugs	Medical and precision instr.
Chemicals, except drugs	Rubber and plastic products	Rubber and plastic products	Medical and precision instr.	Chemicals, except drugs
Pharmaceuticals	Machinery, except office	Machinery, except office	Pharmaceuticals	Pharmaceuticals

But, as observed earlier, industrial sector is unlikely to be the unique factor that induces firms to perceive patents more important. That is why a large variability in the number of patent applications can be observed at firm level, even within industries where patents are apparently not important. Thus, the control for other effects is important and one should draw attention to the estimates controlling for industrial sectors (Appendix 4), where the baseline is the Printing and Publishing industry. For the sake of clarity, the estimates shown are compared to the aggregate importance of patents from Table 6. They are reported in Table 7 in ascending order of magnitude from top to bottom. It seems that model (3) and model (4), in particular, have a better match with the results reported in Table 6 than have models (1) and (2), especially model (1) where there is no statistical evidence that the importance of patents differs across sectors.

Perhaps the apparent non-variation of the importance of patents across industrial sectors in model (1) can be explained by the average firm size of the sample. As the firms in model (1) have on average a larger size than the firms of model (2), this may not allow an adequate comparability across industries because we may end up comparing larger firms across industries. It might be that larger firms' perception of the importance of patents varies across industrial sectors but not to the extent that an opinion-based scale could capture. As in model (3) this scalability issue is, at least in part, controlled for by the SAI index in that model the expected variability across sectors can be observed. This is also so for models (2) and (4), which lend support to hypothesis H7 that the importance of patents varies across industrial sectors.

A few remarks should be made about the performance of the estimated models. Firstly, as the chi-squares of the models are all significant at 1% level the hypothesis that all coefficients equal zero can be rejected. Secondly, models that take into account appropriation intent have their goodness of fit enhanced as compared to models where this variable is absent. Moreover, models using percentage of personnel with science/ engineering degree to control for innovative capacity seem to outperform, in terms of goodness of fit, models using R&D intensity for the same purpose. However, a degree of caution should be exercised when examining this. All models in Table 5 differ as to their sample size because of non-responses. Thus, it would be more sensible to compare estimation models using the same sample. So, if the models are limited to the same sample, the ones which use R&D to control for innovative capacity perform slightly better than the ones using percentage of technical staff[128]. Conversely, Akaike's information criterion (AIC) presented in Table 5 seems to favour models with percentage of staff holding a science/ engineering degree. As R&D poses some restrictions on the analysis, perhaps models (2) and (4) are stronger candidates to be the final model.

Thirdly, models (3) and (4) outperform models (1) and (2), respectively. This gives support for taking appropriation intent into account, and hence model (4) would be the preferred model. But in taking the appropriation index into account other issues emerge. For example, it is arguable whether patents themselves are conducive to a higher overall appropriation intent index rather than the opposite. That is, there is a possibility of this index being correlated to the residual of the patent importance variable, and then being endogenous as opposed to exogenous, as we assumed. In this case, the Rivers and Vuong (1988) test could be carried out. The problem, however, is that despite its simplicity and consistent estimates produced, that test was developed for binary models,

[128] Sample size=413; model (1): pseudo-R^2=0.1063, AIC=2.380; model (2): pseudo-R^2=0.0989, AIC=2.399; model (3): pseudo-R^2=0.2314, AIC=2.071; model (4): pseudo-R^2=0.2300, AIC=2.075.

not for ordinal ones. To the best of our knowledge there is no endogeneity test for ordinal outcomes. And even if appropriation intent was detected to be endogenous, our data set, although large, is limited with respect to adequate instruments to correct for endogeneity[129]. We, therefore, leave this for future research.

Finally, the proportional odds assumption was checked comparing the log likelihood of the estimated models with their binary counterparts, that is, pooling a number of binary models equal to the number of categories minus 1 (three in our case). For all models the assumptions made could not be rejected[130]. That is, the impact of each variable is the same on each category of the response variable, though this assumption is weaker for models (3) and (4).

4.6 DISCUSSION

It emerges from the results that larger firms are more likely than smaller firms to consider patents as of high importance, which makes us not reject hypothesis H2. It is not a surprise that larger firms apply for a larger number of patents than smaller firms do. In fact, previous studies have shown firms' propensities to patent to be positively associated with firm size (Scherer 1983, 1965). As patenting activity demands availability of resources for the application and enforcement of patents it is likely that larger firms have an advantage over smaller firms. Besides, economies of scale apply to this type of activity. So,

[129] Had instruments been found, bootstrap should be carried out to correct standard errors

[130] Model (1): p-value=0.5482; model (2): p-value=0.2900; model (3): p-value=0.0961; model (4): p-value=0.0613.

larger firms may incur relatively lower costs as compared to smaller firms. As a consequence larger firms are more likely to build up a patent portfolio seeking higher barriers to entry, as also suggested by our interviews in pharmaceuticals (chapter 3). Smaller firms, in turn, by having more limited resources are less likely to build and to manage a portfolio of patents.

On the other hand, even if smaller firms do not have the financial resources to secure a large portfolio of patents, they could regard patents as important as larger firms. So, our actual findings could not be totally expected. However, as we observed from the interviews (chapter 3), patents seem to be more beneficial to firms if a portfolio approach is used. Perhaps the results are suggesting that being large is not just a matter of having more financial resources but also a matter of being more resourceful in a broader sense. The existence of well defined personnel to deal with patent matters is more likely to be found within larger firms than within smaller firms. Thus, the presence of a more formal structure to deal with patent issues may not only enable firms to more easily monitor their rivals' patents but also give them a better perception of the role played by patents in their competitiveness. And as larger firms are more likely to devote more time and effort to patenting issues they would be more likely than smaller firms to regard patents as more important.

The results of a previous study by Taylor & Silberston (1973) for the UK did not find evidence to support the hypothesis that firms' propensities to patent increase with firm size. Our findings contradict Taylor & Silberston's but are in line with other non UK studies. Has there been any change in the UK in this respect? Possibly not. Although the econometric framework employed in this study differs from Taylor & Silberston's, there is no particular reason to believe that this would lead to a different result. We conjecture that the reason underlying such differences rests with sampling issues. Perhaps their results rely upon a sample with much smaller size variability than ours, or their sample does not contain smaller firms. Even so, it is difficult to explain why, because our estimates based upon a sample of larger firms (when controlling for R&D) point in the same direction: the larger the firm, the more likely it is to place a higher importance on patents.

For obvious reasons, on the basis of the data set used, there is no proper explanation to justify why larger firms are more likely to perceive patents to be more important than are smaller firms. It might be true that, in general, larger firms are those already established in the market and presenting in many cases a technological lead over competitors. Thereby, patents being deemed more important by larger firms than by smaller firms may portray the pursuit of enhancing market power of the former. Although the pre-empting power of patents is said to be marginal (Levin et al. 1987; Gilbert & Newbery 1982), and patents are not priority when UK firms set up their strategies to compete against incumbents and newcomers (Singh et al. 1998), patents may add sufficient value at the margin (Cohen et al. 2000). Yet, it seems that more value is added to larger firms than to smaller ones. What, perhaps, can be asserted from the results is that when the crude number of patents is used to measure innovativeness there might be a bias towards larger firms; thus, we might be underestimating smaller firms innovative capacity.

In terms of public policy not much can be said for we do not have evidence about the reasons underlying such behaviour. A recent study by Derwent (2000) extends the initial study of Hall et al. (1999) for the UK to the European scale. As it is particularly concerned about SMEs it might be helpful. For example, that study found that SMEs in the UK are less likely to apply for patents than their European counterparts. A particular reason for not pursuing patent protection pointed out both by UK SMEs and other European SMEs was that patents are not relevant for their line of business. There is also a belief that the patent system does not fit SMEs needs. Moreover, the threat of litigation puts smaller firms outside the patent system. It is argued by that study that such behaviour reflects a poor understanding of the patenting process by smaller firms. That study advocates that a SME-oriented campaign could be valuable to elucidate patenting issues. But this view may not necessarily be true if most SMEs are not innovative. The justification, therefore, as to the irrelevance of patents for their line of business may be true, especially because it is likely that small firms produce quite different products than large firms in the same sector. So, a policy oriented towards smaller firms should perhaps be segmented by the needs of these firms that might not necessarily be patents *per se*. But if a patent policy is of concern there is still a question: Is such effort worth it? As patenting is a sporadic activity, and dynamic economies of scale are only found after a somewhat high threshold (Geroski et al. 1997), perhaps little can be done to change SMEs perceptions. Nevertheless, a broader spectrum of smaller firms could be motivated to use the patent system if more attention from policy makers was devoted to post-patenting issues such as renewal, out-licensing, and especially litigation (Kingston 2001).

Innovative capacity was detected to be positively associated with an increase in the importance of patents, when appropriation intent was not taken into account. Thus hypothesis H1 that the more innovative a firm, the more likely it will be to place a higher importance on patents could not be refuted. Innovative capacity was also explored under an *ex-post* form by measuring how the introduction of a product novel to the market would impact on the importance of patents. The results converge to the same point: the more innovative firms in UK manufacturing seem to regard patents more important than the less innovative ones do (at least according to the metrics used in this study). We recognize, however, the limitations of the metrics employed. Unfortunately, there was nothing we could do to improve the 'quality' of the metrics used. Hence these limitations should be borne in mind when interpreting the results. For example, having a higher percentage of personnel with a technical background may not make a firm more innovative. Also, the *ex-post* measurement used is very subjective since introduction does not mean commercial success. And even if it were able to describe commercial success it would not reveal the extent of this success.

As the findings regarding innovative capacity are not based solely on R&D, smaller firms are also being 'heard'. Thereby, it seems fair to argue that these results are in line with our expectations. Nevertheless, regardless of the metrics used, what the findings suggest is that if patents are more important for the most innovative firms, they might to a certain degree be playing their role in fostering innovation. As a result wealth creation might take place (though it is not known whether higher R&D intensities are a result of patent races and, therefore, common pool problems are eroding wealth creation). Our data set does not allow us to go deeper into whether patents are fostering innovation, an issue of concern for policy makers. Nevertheless, in controlling for firm size our estimation results regarding innovative capacity indicate that being small does not preclude a firm from regarding patents as important, as long as this smaller firm is an innovative one. Thus, smaller innovative firms and larger innovative firms seem to assign a higher importance to patents than their less innovative counterparts do. Thus, a patent policy oriented towards high-tech start-up firms may be pointless if it just underpins small high-tech firms' existing perceptions of the importance of patents. From a managerial standpoint, the results suggest that more attention should be paid to patents when, regardless of firm size, relatively large resources (and time) are being devoted to the creation of technological innovations.

Another result from this study is that partnerships with universities seem to influence the perceived importance of patents. Firms which set up partnerships with universities are more likely to regard patents as more important than firms that do not establish this type of partnership. Thus, hypothesis H5 was not falsified. This result could be expected to a certain degree since firms may wish to avoid losing proprietary control over the output of this type of partnership. Especially, because it is well known that an important element of university researchers' reputation building process is the sharing of their work with their peers. If they do so before a patent is applied for, property rights will not be secured. Hence, firms engaged in this type of collaboration will be better off if they seek patent protection before the invention is publicly disclosed somewhere else.

The question that arises is whether this would also hold for other types of partners. To understand whether the nature of the partner causes any change in the perceived importance of patents, parallel models were estimated investigating how the estimates for partnership differed across types of partner. More specifically, four other partners were studied: firms within own group, suppliers, clients, and competitors. The results are reported in Table 8[131]. Somewhat surprisingly, the results are that for no other partnership is the importance of patents increased. That is, only joint-innovation projects with universities seem to be conducive to a higher likelihood of firms assigning a higher importance to patents. This might be a surprising result because a previous study of Brouwner & Kleinknetch (1999) indicates that R&D collaborations increase firms' propensities to patent. We should then expect a positive (and significant) impact of the estimates of innovation partner variable on the importance of patents.

[131] The same sort of results were achieved in models (3) and (4).

Table 8 - Effects of Innovation Partner on the Importance of Patents

Type of partner	Variants of model (1)			Variants of model (2)		
	Coeff.[a]	Wald test	p-value	Coeff.[a]	Wald test	p-value
Within group	-0.029 (0.255)	-0.11	0.909	0.142 (0.179)	0.79	0.428
Suppliers	-0.221 (0.246)	-0.90	0.370	-0.013 (0.175)	-0.07	0.941
Customers	-0.034 (0.244)	-0.14	0.888	-0.158 (0.179)	0.88	0.378
Competitors	-0.359 (0.438)	-0.82	0.413	0.015 (0.294)	0.05	0.959
Universities	*0.608 (0.250)*	*2.43*	**0.015**	*0.506 (0.189)*	*2.68*	**0.007**

[a] Robust standard errors in parentheses.

One possible interpretation rests with empirical evidence by Hagedoorn et al. (2003) that the number of joint-patents is positively associated with previous experience in sharing this type of property rights and is not associated with previous R&D alliances. So, it may be that firms have learned to share property rights with universities more quickly than with other partners. The findings might also be a result of the degree of innovativeness involved in partnerships of this type. Although the innovation process receives feedback from various sources (von Hippel 1988), collaborations with universities in research projects are likely to comprise innovations of more exploratory, or basic, nature. That is, there seems to be a movement of industries towards science base (Trajtenberg et al. 1997). On the one hand, it can be argued that the basic character of university research does not lead to patentable subject matter (one of the patentability criteria is for the invention to have industrial applicability). On the other hand, the output of a joint-project with a university is more likely to be a breakthrough innovation than the output of other types of collaborations, though this argument can be disputed.

Adding to that, relationships between researchers are not only built over time but also dependent on successful and trustful exchanges (Bouty 2000). Are the findings suggesting that this trustful exchange between private firms and universities still needs to be consolidated? It is very unlikely that this is the driving force. We conjecture that the very nature of the university researchers' profession described earlier (i.e., scientific publications) is determinant. If so, it is likely that firms consider that knowledge generated from partnerships with universities is more likely to leak out than with other partners, and hence stronger appropriability should be exercised. So, the results could be suggesting a more defensive approach to information disclosure than to the control of property rights (or the importance of the output itself) when university collaborations are consolidated. For obvious reasons, technological collaborations with other partners also demand the exercise of proprietary control. However, as public disclosure is of less concern with respect to other types of partners than with universities, what is likely to be at stake is the extent of the control of property rights itself, rather than the disclosure of information. In addition, universities have increasingly seen collaborations with industries as an important source of revenue and income (Panagopoulos 2003), which means that they need to fulfil industries expectations if a successful relationship is aimed; certainly, an important issue regards intellectual property rights.

Perhaps these results are good news for policy-makers because one possible interpretation is that the tax payers' contribution might be productive, that is, it results in potentially useful innovations. Moreover, the strengthening of appropriability conditions in this type of partnership may be one of the alternatives to stimulate a closer relationship between industry and academia. However, this is debatable because if the outcome of these partnerships is publicly funded, appropriation of the results by a few agents may not necessarily be desirable. Although the data available do not show the structure of these partnerships, or the nature of the outcome of these partnerships, the findings may suggest that innovation collaboration between firms and universities should not be overlooked by policy makers. Thus, as suggested by Foray & Steinmueller (2003) a policy is needed to preserve and, maybe, stimulate this type of partnership and it has to be a careful one because, according to the authors, such collaborations have to fulfil the expectations of private firms as to appropriability conditions without missing the sense of collectiveness.

Further evidence from the estimated results indicates that patents become more important when competition is more severe. The results suggest that competition is likely to be conducive to an increase in the perceived importance of patents. Even when appropriation intent is controlled for, there is a relationship between a higher level of competition and the importance of patents. Although when R&D intensity is taken into account competition has no impact on the importance of patents, the impact of market structure should not be ignored. This is because R&D intensity represents to a certain degree the level of competition a firm faces. Moreover, the average size of firms in the sample is larger when R&D is accounted for than when R&D is not accounted for. Therefore, those who invest in R&D are very unlikely to focus their activities simply on local or regional markets (no more than 100 miles from where they are located). Further, the UK competitive environment needs not necessarily lag behind the international arena and firms (larger ones, in particular) may need to seek the same level of competitiveness than multinationals. On the one hand, under severe competition deficiencies of patents can be more noticeable, but on the other their virtues can be more pronounced. Thus, the importance of patents seems to be sensitive to the size of the market where a firm operates (which is a proxy for level of competition). Our results re hypothesis H3 (i.e., the higher the level of competition a firm faces, the more likely it will be to place a higher importance on patents) suggest we cannot reject it.

The results also indicate that the relationship between the importance of patents and the support received by the government is positive and significant, if appropriation intent is not taken into account and the sample is not restricted to larger firms on average. That is, hypothesis H4 (i.e., firms that receive government support are less likely to place a higher importance on patents) could be rejected. However, the estimate for government support in model (1) is not only insignificant but also goes in the opposite direction of the coefficient of model (2). It seems that size of the respondent plays a role in the relationship with government. Perhaps the government supports smaller and larger firms in different ways, or even their own size makes them perceive the outcome of their relationship with government differently.

Thus, larger firms could perceive their relationship with the government as somewhat harming the private returns they could get from exclusive property rights granted by a patent. Smaller firms, however, may perceive that one of the incentives given by government is the possibility they have to enforce their intellectual property rights, and hence compete against larger firms. This argument seems to receive support from an analysis of the composition of the sub-samples which declared to have received government support. The sub-set of firms that declared to have received support in model (1) consists of 56% of small, medium-sized firms (less than 250 employees) and 44% of large firms (250 employees or above). In turn, the group of firms that reported to have received government support in model (2) is composed of 75% of small, medium-sized firms and 25% of large firms. Thereby, if our reasoning is correct, a larger proportion of smaller firms receiving support from the government is conducive to a higher likelihood of assigning more importance to patents (holding other things constant). Therefore, if patents are more important to larger firms than to smaller ones, this turns the other way round when they receive government support for their innovative activities.

Patents can be a strong or a weak protective device, and engineering around patents is likely to be the norm rather than the exception. On other occasions patents can be very effective in stopping others from coming up with a competing alternative to the existing innovation. Notwithstanding, firms are not expected to rely solely upon one mechanism to build up a tighter appropriation, though under certain circumstances a particular mechanism can be more adequate than others. Mansfield (1985) observed that information leaks out. But if information may leak out, it may also leak in. This means that firms' appropriation is an exercise in controlling flows of knowledge and this control, according to the results that examined the importance of patents, seems to depend on the appropriability regime under which a firm operates. The observed variability of the importance of patents across industrial sectors did not reject hypothesis H7, indicating that patents are not only important for pharmaceutical firms.

In general, the rejection (or not) of the hypotheses above was made not regarding the impact of appropriation intent. Had appropriation intent been accounted for, a few results would be different. Although it seems that the overall appropriation intent exercises a strong influence on the perceived importance of patents, the index (SAI) created to measure this intent has limitations that could not be overcome. The four-point scale used in the questionnaire will always give a margin for criticism because, for example, what means 'high importance' for one firm in an industry may have a different meaning for another firm in another industry. Moreover, the findings cannot be extrapolated beyond the mechanisms used in the questionnaire. For example, as there was no space in the questionnaire for trade secrets, 'secrecy' should be interpreted as keeping things secret by any means rather than a confidentiality agreement contract. Thus, there is 'room for improvement' in this respect.

So, the results from other models (model (2), in particular) should not be disregarded. Despite the limitations of the appropriation intent index, it is hard to believe that hypothesis H6 (i.e., the higher the appropriation intent of a firm, the more likely it will be to place a higher importance on patents) should be refuted, though one may cast doubt on the magnitude of the impact. An alternative to the index created would be to use factor analysis. This would be more useful if we were investigating how other mechanisms of appropriability are related to patents, and this is, in fact, investigated in the next chapter.

4.7 Conclusions

Patents have long been used as indicators of inventive activity, although the limitations of this practice were always known. A body of empirical work has emerged that examines R&D productivity by means of investigating the patent-R&D relationship. That empirical literature has explored what makes one firm more inclined to patent than others. Such evidence has also proved to be useful for those interested in the patent system because it is, even if imperfectly, a documentation of who benefits most from that system. Thus, the usefulness of the patent system in correcting market imperfections can be analysed.

Holding other things constant, we assume that patents are more important for those who use them most. So, we expect that the attributes that make firms patent more are the same that make them perceive patents as of higher importance. Nevertheless, the empirical literature has also shown that there are a number of reasons patents are applied for that go beyond the protective purpose (e.g., attracting financial resources, strategic behaviour). Moreover, actual facts reported by the empirical literature suggest that even when patents are not very effective as a means of protection they are applied for. As a result, in using patent numbers to measure the importance of the fundamental attribute of the patent system (i.e., stop copying), the results could be misleading.

This chapter advances our existing knowledge on that point by examining what firms' attributes make them perceive patents more (or less) important as a protective device. We use ordered logit models to analyse a unique survey-based data set from the third round of the UK Community Innovation Survey (CIS 3). Our results, to a large degree although not totally (see below), match previous studies of this kind. This suggests that contrary to our expectations patent numbers may be a good proxy for evaluating the importance of patents as a mechanism of protection, but only if firms' other attributes are controlled for. This also suggests that despite the multifaceted role played by patents the main purpose of those who use the patent system is to protect their inventions against copying. However, our results reinforce the view that the use of patents as an innovation indicator needs to be carefully interpreted because they may understate the innovativeness of firms for a number of reasons (e.g., size, industrial sector).

Overall, our findings are that one cannot reject the hypotheses that i) the importance of patents varies across industrial sectors and by firm size, ii) patents are more important for firms with greater innovative capacity, iii) competition is to a certain extent conducive to a greater importance for patents, iv) innovation collaboration and government support may increase the importance of patents depending on the agents engaged in these activities, and v) the importance of patents is also dependent on firms' appropriation intent.

Contrary to Taylor & Silberston's (1973) findings for the UK, our results indicate that propensities to patent in the UK do vary by firm size. We conjecture that the reason underlying our different result rests with sampling issues and not with reduction of the importance of patents amongst smaller firms over time.

Another difference between our results and an earlier study on firms' propensities to patent regards the impact of innovation collaborations. Brouwner & Kleinknecht (1999) studied propensities to patent in the Dutch manufacturing industry and found that R&D collaborations positively impact on those propensities. Our results corroborate their results only in part; we found that in the UK firms that have established joint innovation collaborations with universities deem patents as of more importance than firms that have not set up such a partnership. But, somewhat surprising, we did not find that the same applies to other types of partnerships. As the estimates of Brouwner & Kleinknecht (1999) are at more aggregate level than ours we do not know to what extent our results really differ. As partnerships and intellectual property seem to have become topical, and on the basis of our existing knowledge, it seems important to ask why different partners impact differently on firms' propensities to patent; an issue that clearly deserves future research.

Our findings have also shown that firms' interest in appropriation is conducive to more emphasis on patent protection, though our analysis has the limitation of not identifying what makes firms be more (or less) interested in appropriation. If appropriation intent mirrors firms' strategies, an avenue of research that could be followed is the examination of patents *vis-à-vis* other mechanisms in firms' appropriation strategies. Especially because the explanation for that result may lie in one of the limitations of this research, that is, the way appropriation intent is measured.

Although we have examined several attributes relating to firms' perception of the importance of patents, a clear limitation of our study is that we have not been able to identify whether the direction of the causality is correct[132]. In the absence of a proper technique to answer this question within the econometric framework employed we leave this enterprise for future research. Another limitation of our investigation regards the measurement of the importance of patents. As our metrics relies on a likert-type scale, it is difficult to predict the consistency of respondents answers[133]. Moreover, it is hard to assess whether the perception of importance of patents was described in general terms, or on the basis of the most valuable innovations.

[132] For example, more innovative firms were detected to place more value on patents. Could it be that because patents are perceived very important that firms invest more in innovative activity?

[133] Arundel (2001) proposes a method to overcome the potential problem of internal consistency of respondents' answers, which relies upon differences in the importance of appropriability mechanisms.

CHAPTER 5

THE IMPACT OF THE IMPORTANCE OF APPROPRIATION MECHANISMS ON THE DECISION TO PATENT AND THE LEVEL OF PATENTING

5.1 INTRODUCTION

Creation of knowledge may not necessarily bring competitive advantage if rivals hold other complementary assets that mitigate the returns accrued to the knowledge generator, or if rivals are able to easily duplicate this knowledge (Teece 1986). In order to avoid, at least in part, the erosion of profits from their knowledge assets firms need to control various appropriability mechanisms accordingly. For example, although knowledge can be kept secret from rivals, this is not always possible (sooner or later they may have access to it). Alternatively, knowledge can be disclosed to a certain degree but, at the same time, it can be made non-tradable by rival firms. To this end, intellectual property rights can be secured. Moreover, firms can rely on lead-time advantage in an attempt to appropriate the rent streams as much as possible before a competing alternative emerges. Further, a firm can build upon its capabilities to create innovations that are so complex that other firms are not able to imitate for their lack of equivalent capabilities.

Thus, attention to the use of appropriability mechanisms is an important approach, though not enough, to understand how firms capture value from knowledge assets. If on the one hand the literature has recognized the importance of these mechanisms (e.g., Winter 2000; Teece 1986), on the other hand little is known as to whether they complement or substitute for one another. In this chapter we advance current knowledge by looking at how various mechanisms are related to patents, though we do not go as far as asking how they are related to one another. In particular, we study how firms' perception of the importance of several mechanisms of appropriability impacts on the decision to patent and the level of patenting.

Following a similar structure to the previous chapter, the next section puts the research hypotheses forward. The third section describes the variables used in the estimated models. The fourth section explains why a particular econometric framework was employed. The fifth section presents the findings. The sixth section discusses the results. Finally, in the seventh section, conclusions are drawn.

5.2 HYPOTHESES

The literature reviewed in chapter 2 detected a dispute as to the complementary or substitutability of mechanisms of appropriability, especially patents and secrecy. This chapter examines the interaction between patents and other appropriability mechanisms. For the sake of simplicity, the substitutability standpoint is addressed in most operational hypotheses below, though there is no particular bias against the contrary. It is assumed that if the substitutability stance prevails a higher importance given to a particular mechanism of appropriability has the opposite effect on both the decision to apply for the first patent and, given that the first patent application is filed, the number of patents applied for. The hypotheses were formulated in pairs; one relating to the decision to patent and another relating to the number of patents applied for. A number of reasons explain this approach, and are described later in this chapter. Perhaps the main reason is that such an approach gives better visibility to the relationship between patents and other methods of appropriation. The following hypotheses were tested:

H8a: The more important secrecy is perceived to be, the less likely a patent will be applied for.

H8b: The more important secrecy is perceived to be, the lower the level of patenting, *ceteris paribus.*

H9a: The more important another category of IPR is perceived to be, the less likely a patent will be applied for.

H9b: The more important another category of IPR is perceived to be, the lower the level of patenting, *ceteris paribus.*

H10a: The more important lead-time is perceived to be, the less likely a patent will be applied for.

H10b: The more important lead-time is perceived to be, the lower the level of patenting, *ceteris paribus.*

H11a: The more important design complexity is perceived to be, the less likely a patent will be applied for.

H11b: The more important design complexity is perceived to be, the lower the level of patenting, *ceteris paribus.*

H12a: The higher the appropriation intent of a firm, the more likely a patent will be applied for.

H12b: The higher the appropriation intent of a firm, the higher the level of patenting, *ceteris paribus.*

The set of hypotheses that do not assume that patents and other mechanisms are substitutes are those which infer the impact of appropriation intent on the decision to patent and level of patenting (H12a and H12b). The substitutability standpoint is not assumed in the construction of our *proxy* for appropriation intent because of operational constraints (mathematical convenience, more specifically).

5.3 VARIABLES

Similar to the previous chapter, the variables employed in our regression analysis come from the CIS 3 questionnaire, and they were used to test the above hypotheses. Most variables used in the estimation of the model in this chapter were employed in the regression analysis of the previous chapter. They are described here again in order to reinforce the reasons underlying their use.

Response variable

(i) **Patenting.** Our dependent variable is the number of patents applied for in the period 1998-2000, and thus is a non-negative integer. A zero outcome means either that a firm had no patentable inventions or that it decided not to apply for a patent although having a patentable invention. The number of patent applications comes from the first part of the question 15 of the CIS 3 instrument that asks the following:

> *"How many patents, if any, did your enterprise apply for during the period 1998 to 2000?"*

Explanatory variables

(i) **Appropriability mechanisms**. The main objective of this study is to examine how an emphasis on a particular appropriability mechanism impacts both on the decision to patent and on how many patents to apply for. In the absence of a better measure for the extent that a mechanism is used, the degree of importance of each mechanism is employed instead. This proxy derives from the item 2 of the question 15 of the survey instrument, as described elsewhere (chapter 4) in this thesis. Incorporating these variables in the model we can test most of our research hypotheses. So, the importance assigned to confidentiality agreements and/ or to secrecy tests hypotheses H8a and H8b. Hypotheses H9a and H9b are tested by the parameters of the model which employs the firms' perception of the importance of copyright, registration of design, and/or trademarks. Firms' perception of the importance of lead-time is used to test hypotheses H10a and H10b. Finally, hypotheses H11a and H11b are tested by the results of the model using the importance of the complexity of the design of the innovation.

(ii) **Appropriation intent**. Although the use of each individual mechanism might suffice, an analysis based upon each mechanism does not allow an understanding of the full picture, i.e. how appropriation intent is correlated to the decision to patent and to the level of patenting. To overcome at least in part this limitation a composite of the mechanisms is used. This variable (described in chapter 4 as SAI index) accounts for the overall appropriation intent, that is, it is assumed that the more (and to a greater extent) mechanisms are used the more firms intend to appropriate the returns from their innovations. This, however, does not mean that they succeed. Nor does it mean that they have a better performance than their counterparts. In addition to the 'stated appropriation intent' (SAI) index, we also employed a composite variable derived from factor analysis. This is a step forward compared to the analysis carried out in the previous chapter because it allows us to overcome some deficiencies presented by our index, such as the same weight on each mechanism in firms' appropriation strategies. Thus, hypotheses H12a and H12b can be tested accordingly. More details on the 'factor' variable will be given in the section that presents the results.

Control variables

(i) **Innovative capacity (*ex-ante*).** In many ways the number of patents derives from the number of patentable inventions available, although this may not necessarily apply. The reason is that firms can apply for several, and somewhat similar, patents at the same time in order to decide later which application will progress in the patent office. Talks with personnel dealing with patent issues, however, have shown that this is not very common, especially regarding smaller firms. Also, the number of patent applications and number of inventions do not have a 1:1 relationship. However, it is commonly accepted in the literature (Hall & Ziedonis 2001; Cincera 1997) that the number of patents is a result of firms knowledge stock, for which R&D expenses are widely used as a *proxy*. One would expect patents to be applied for after R&D expenses have been incurred, and hence past R&D would be most suitable for our estimations. However, due to the high within-firm correlation of R&D

over time and its marginal change the results of using a lagged structure are roughly the same as the results with contemporaneous levels of R&D (Blundell et al. 2002; Hall & Ziedonis 2001; Pakes & Griliches 1980). Thus, our R&D expenses are for the year 2000. We use R&D in its logarithmic (natural) form in order to linearise the relationship between R&D and patents for in most regressions of this type log values result in a better fit (as measured by the log-likelihood) than the inclusion of the level values of the variables (Liao 1994). We also use another proxy for measuring knowledge stock (ex-*ante*), namely the percentage of staff holding a scientific/ engineering degree. The advantage of this variable as compared to R&D outlays is that the latter may provide biased results towards larger firms since smaller ones may not report this cost for not having formal R&D function. As a starting point, we briefly compared the two models[134]. Although the results have shown that R&D is a better proxy to capture patent-related innovative activity, by accounting for R&D not only the sample size is reduced but also smaller firms are underrepresented[135].

(ii) **Innovative capacity (*ex-post*).** A dummy variable for whether or not a firm introduced a product new to its industry was used. This variable may portray a firm's degree of innovativeness because by being novel to

[134] The results can be provided upon request.

[135] When R&D is accounted for the sample average sales and number of employees are of approximately 51.2 million pounds and 323, respectively. In turn, when percentage of personnel holding technical skills is employed the average sales and number of employees are reduced to 19.9 million pounds and 174 employees, respectively (figures for year 2000).

the whole industry the product is new to not only the innovator, and therefore it differs from existing innovations. We use an *ex-post* variable for innovative capacity because it may supplement any deficiency that the *ex-ante* innovative capacity variable may have, since this characteristic may be pivotal in determining patenting activity (Cohen 1995).[136]

(iii) **Firm size.** Size may pick up a set of firm characteristics, such as scale economies in the patenting application process. So, different number of patent applications can be a result of firms' capacity to allocate more resources to patenting rather than being more (or less) innovative (Licht & Zoz 2000; Scherer 1983). To measure firm size we used the logarithm of its turnover in the year 2000. Differently from other variables used in our analyses, this variable derives from the IDBR records. The best-fit rationale for the logarithmic form of R&D also applies in this case. The number of employees was also used in order to account for firm size, but there was no significant difference in the results that would justify its use as opposed to turnover.

(iv) **Size of market.** As the question about the number of patent applications does not differentiate between patents applied for to the UK Patent Office and to other Patent Offices worldwide, it is likely that firms

[136] We have also examined that the relationships between the *ex-ante* and the *ex-post* variables are not strong enough to cause collinearity.

having operations abroad have patent applications abroad as well[137]. As a result a larger number of patents would not indicate that a firm is more innovative but rather that either it operates in various markets or it foresees trading in these markets in the near future (Patel & Pavitt 1995). So, indicator variables were introduced to represent firms' largest markets. The reference market was initially chosen to be the national one, and the estimates reliant upon the following markets: i) local (situated within approximately 50 miles), ii) regional (situated within approximately 100 miles), and iii) international.

(v) **University partnerships.** A dummy variable was employed to control for companies that establish innovation partnerships with universities. Nowadays there is an increasing pressure for universities to appropriate their knowledge (Henderson et al. 1998).

(vi) **Government support.** It has long been recognized that government support interferes in patenting activities (Taylor & Silberston 1973; Scherer 1965). The literature advocates that patents may become less important for those firms that receive support from the government, especially financial support. So, the incentives for innovators to pursue patent protection would be limited when this type of support is received. According to Griliches (1990), one possible reason is that governmental support implies a modest license fee to be charged if other firms become

[137] It does not mean that those which do not have operations abroad have not pursued international patent routes. This can happen if firms envisage a possibility of exploring the innovation in the corresponding

interested in the innovation. Although this argument may not necessarily hold nowadays, or this does not at all apply to the UK, we introduced a dummy variable to account for this possibility.

(vii) **Industry.** This study does not focus on the industry level but rather on the firm level. As the number of patents may vary across industrial sectors (Scherer 1983), a series of dummies, reflecting different market conditions, could be controlled for. We used a single dummy instead, which distinguishes industries where the commercializable final innovation consists of numerous separately patentable elements ('complex' innovation based industries) from industries where relatively few elements comprise the marketed innovation ('discrete' innovation based industries). This is in line with recent studies[138] (e.g., Cohen et al. 2002; Kusonaki et al. 1998). Appendix 5 gives some detail as to how these industries differ from each other. The 'complex' industry has a higher average number of patent applications than has the 'discrete' industry, though the latter has a larger range[139]. As we shall see in the next section they do not seem to be significantly different in statistic terms. The 'complex' industry has also a higher mean proportion of staff holding a scientific/ engineering degree. In turn, the 'discrete' industry accounts

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country in the future.

[138] Following Cohen et al. (2002) procedure, industrial sectors with UK SIC 92 codes less than 29 (e.g., food, beverages, and tobacco, chemicals, pharmaceuticals, metals) were categorized as 'discrete' whereas 'complex' industries were assigned to sectors with UK SIC 92 codes 29 or above (e.g., machinery, communication equipments, medical, precision and optical instruments, office and computing equipments).

[139] The maximum number of patent applications (300) comes from pharmaceuticals.

for a larger average sales. Both industries supply mainly the national market; but the complex industry is more internationally oriented than is the discrete one. In terms of estimation, the use of several industry dummies allows the models to have a better goodness-of-fit (pseudo-R^2), but the overall model performance (AIC, BIC)[140] seems to improve when a single dummy is used to control for 'complex' industry instead (see Appendix 6).

The variables above were used to empirically test our research hypotheses. For the sake of parsimony we undertook an analysis to select a base specification model before estimating the models with the explanatory variables of interest; the analysis is described later in this chapter before presenting the results. The econometric framework within which our regressions were run is described in the next section.

5.4 ECONOMETRIC FRAMEWORK

In using the number of patent applications as dependent variable our estimation techniques have to take into account the non-negative integer nature of this variable. Thus, it departs from the traditional least squares estimation by using a specification that accounts for such characteristic. The framework of count data models is, therefore, the most appropriate in this case (Greene 2003).

[140] The Bayesian Information Criterion (BIC) imposes a greater penalty for additional parameter than does AIC. BIC tends to be more consistent and efficient than AIC (Shono 2000).

This category of models has been refined in many cases by the study of the R&D-patents relationship[141].

A starting point for the study of count distribution is the Poisson model. It specifies that each y_i (number of occurrences) is drawn from a Poisson distribution with parameter λ_i. The probability density of y_i is given by

$$\Pr(Y_i = y_i) = \frac{e^{-\lambda_i}\lambda_i^{y_i}}{y_i!}, \qquad y_i = 0, 1, 2, \ldots \tag{5.1}$$

where λ_i is related to the regressors $\mathbf{x}_i$ in a log linear form to ensure its non-negativity

$$\ln \lambda_i = \mathbf{x}_i'\boldsymbol{\beta} \tag{5.2}$$

while $\boldsymbol{\beta}$ is the associated vector of unknown parameters. Thus, the Poisson distribution has expected value λ, and has variance λ as well. This equality of the two conditional moments is a characteristic of the Poisson distribution, and is referred to as equidispersion. In many cases, however, a violation of the variance assumption is observed and as a consequence, in contrast to other multi-parameter distribution, a violation of the Poisson assumption is also observed (Winkelmann 2003). Departures from equidispersion can be underdispersion (variance smaller than the mean) or overdispersion (variance larger than the mean). Overall, it is not uncommon to find the latter in patent counts. A possible reason for such phenomenon is the existence of unobserved

[141] See, for instance, Blundell et al. (2002), Blundell et al. (1999), Crépon & Duguet (1997a, b), and Hausman et al. (1984).

heterogeneity that makes the Poisson distribution not adequate to explain the number of occurrences of an event. In the patent framework, for example, there are uncertainties and risks inherent to R&D activities as well as to the commercialization of innovations, firms different capabilities and strategies, to name but a few. Moreover, there is a possibility of contagion, which is the influence of past events on the occurrence of future events. Say, for instance, that subsequent patents are applied for because a previous patent application was found to relate to a really valuable invention and the innovator is mining the field with other patents to enhance protection. In this case, this occurrence dependence is also known as positive contagion.

So, in order to relax the restrictive assumption of equidispersion and to better model count distributions where departures from the Poisson distribution are observed other classes of models have been developed[142]. They allow for unobserved heterogeneity by modifying the mean function λ_i with a multiplicative error u_i, that is

$$\tilde{\lambda}_i = \lambda_i u_i$$

where both $\tilde{\lambda}_i$ and u_i are unobserved. It is then assumed that u_i has a known density function $g(u_i)$, and hence the joint density function of y_i and u_i can be expressed as

$$f(y_i, u_i) = f(y_i \mid u_i) g(u_i) \tag{5.3}$$

[142] See Winkelmann (2003) and Cameron & Trivedi (1998) for a more complete survey of these models.

from which the marginal distribution of y_i can be obtained by integrating the joint distribution over u_i. Thus,

$$f(y)=\int_0^{\infty} f(y,u)du=\int_0^{\infty} f(y,\tilde{\lambda})d\tilde{\lambda}. \tag{5.4}$$

As $f(y\,|\,u)$ is assumed to be Poisson distributed we get

$$f(y)=\int_0^{\infty}\frac{\lambda^{y}}{y!}e^{-\lambda u}u^{y}g(u)du \tag{5.5}$$

and $g(u)$ can be a parametric density function or a semi-parametric one[143]. Although robustness can be gained when using a semi-parametric assumption, efficiency is lost as compared to an introduction of a parametric assumption (Winkelmann 2003). One of the most widely used parametric forms of $g(u)$, and of particular interest of this study, is the gamma distribution, which allows the integral above to have a closed form, and hence is mathematically convenient. The result of this Poisson-gamma mixture is the negative binomial model in the form

$$f(y\,|\,\alpha,\lambda)=\frac{\Gamma(\alpha+y)}{\Gamma(\alpha)\Gamma(y+1)}\left(\frac{\alpha}{\lambda+\alpha}\right)^{\alpha}\left(\frac{\lambda}{\lambda+\alpha}\right)^{y} \tag{5.6}$$

where the expected value of y is λ (as in the Poisson distribution) and variance equals to $\lambda+\lambda^2/\alpha$. This negative binomial model with a quadratic variance function is also known as 'Negbin II'. This is so because it can be reparameterized in different ways such that the variance assumes various forms,

[143] Gurmu et al. (1999).

though the expected value remains the same. For example, one of the parameterizations leads the variance to be a linear function of the mean. This variant is referred to by Cameron & Trivedi (1986) as 'Negbin I'. Winkelmann & Zimmermann (1991) proposed a more generalized form known as 'Negbin$_k$' which presents mean λ, as before, but a more generalized variance $\lambda\left(1+\sigma^2\lambda^k\right)$. Negbin I is obtained by setting k=0, and Negbin II by setting k=1. Moreover, if σ equals zero a Poisson distribution is observed. Thus, the Poisson model is said to be nested in negative binomial models.

Unfortunately, neither negative binomial models nor Poisson models might be appropriate if a large number of zero observations is observed - a common phenomenon with respect to patents. These models treat the zero outcomes of the data generating process in the same way as the positive outcomes. In doing so, they neglect that a zero outcome may be a result of another decision-making process, that is, whether or not to apply for a patent, which may be a strategic decision. It is reasonable, therefore, to model this process of deciding to apply for patents differently from the process generating positive outcomes. One approach that takes into account this difference is the hurdle models, where a binomial process is assumed to govern the binary outcome of whether or not apply for a patent and, once the hurdle is crossed, a truncated-at-zero count data model governs the positive values (Mullahy 1986). A problem that arises when applying these models to patents is that they assume that there is only a single type of zero outcome (Gurmu 1998), that is, a decision of not applying for patents. However, zero outcomes can be not only a result of a negative decision as to file a patent but also a consequence of the impossibility of filing a patent because neither an invention is available to be patented nor an invention meets patentability criteria. In order to account for the existence of two regimes governing zero outcomes zero-inflated models seem to be more appropriate, namely zero-inflated Poisson and zero-inflated negative binomial models. Like their hurdle-at-zero counterparts zero inflated models combine a variable c_i, which separates zero outcomes from positive outcomes, with a latent variable y_i^* such that the observed count y_i is defined by

$$y_i = \begin{cases} 0 & \text{if} \quad c_i = 1 \\ y_i^* & \text{if} \quad c_i = 0 \end{cases} \tag{5.7}$$

So, zero outcomes arise either from regime 1 (c_i=1) or from regime 2 (c_i=0, y_i^*=0). Having said that, the probabilities for the outcomes should be identified. If the probability for c_i=1 is denoted by ω_i the probability function of y_i can be defined as follows

$$f(y_i) = \omega_i d_i + (1 - \omega_i) g(y_i) \tag{5.8}$$

where $d_i = 1 - \min\{y_i, 1\}$ and $g(y_i)$ is the count data distribution function (Winkelmann 2003). Thus, the probability function of y_i can be expressed as

$$\Pr(y_i=0) = \omega_i + (1 - \omega_i) g(0) \tag{5.9}$$

$$\Pr(y_i=k) = (1 - \omega_i) g(k), \qquad k=1, 2, 3, \ldots \tag{5.10}$$

In our case, ω_i is modelled following the Lambert specification (1992), that is, as a logit function

$$\omega_i = \frac{\exp(z_i'\gamma)}{1+\exp(z_i'\gamma)} \tag{5.11}$$

where z_i' is the vector of covariates determining the probability of not applying for a patent and γ is the parameter vector.

Due to possible unobserved heterogeneity we will assume that $g(\cdot)$ is a negative binomial probability function. Therefore, our estimation results derive from a zero-inflated negative binomial model and are obtained by maximizing the log-likelihood function of the model, which is given by

$$\begin{aligned}\lambda = &\sum_{y_i=0} \ln(\exp(z_i'\gamma)+\alpha(\ln\alpha-\ln(\exp(x_i'\beta)+\alpha)) \\ &+\sum_{y_i>0} \ln(\Gamma(\alpha+y_i)/\Gamma(\alpha)+\alpha\ln(\alpha-\ln(\exp(x_i'\beta)) \\ &\qquad +y_i(x_i'\beta-\ln(\exp(x_i'\beta)+\alpha))-\sum_{i=1}^{n}\ln(1+\exp(z_i'\gamma))\end{aligned} \tag{5.12}$$

Although there is a reason underlying the choice of the probability distribution function, this assumption is also tested. Likelihood-ratio tests are used to compare nested models (i.e., zero-inflated Poisson) and non-nested models (i.e., negative binomial) are compared by the Vuong (1989) test. The results are reported in the next section.

5.5 RESULTS

Initial remarks

From the outset it should be clear how the estimates of the zero-inflated negative binomial models are interpreted. Following standard estimation techniques the estimates of the count part are interpreted as that a covariate with a positive sign means an increase in the probability of a larger number of patent applications. In turn, a covariate with a negative sign in the decision part means that there is a decrease in the probability that a firm will NOT apply for a patent. That is to say that a negative sign means an increase in the likelihood that a patent will be applied for. Therefore, opposite signs in the decision and in the count parts lend the same interpretation with respect to the probability of a positive outcome.

Model selection

Exploratory models were estimated in order to observe the impact of the replacement of R&D and industry dummies by percentage of scientific staff and complex/discrete industry, respectively. Although the results (Appendix 6) suggest that this specification could be accepted, the initial insignificant results regarding i) largest market dummies and ii) support from the government indicate that a better specification could be sought. In fact, Appendix 5 suggests that there is nearly no difference between regional and local markets with respect to the participation of the 'complex' industry. In a new specification we use both markets as the baseline (model (1) - Table 9). We also observe in model (2), where the share of scientific personnel was not accounted for, that the results are pretty much the same compared to model (1), and an improved model performance is achieved (see AIC and BIC). Thus, for the sake of parsimony, we carried on our analysis without controlling for the percentage of staff with a scientific or engineering degree. Government support did not show any significance in the models in Appendix 6 and in models (1) and (2) in Table 9. The likelihood-ratio test indicated that, in fact, this variable could be removed from the model[144], which led us to model (3) as our base specification (the performance of the model is also enhanced according to BIC).

Table 9- Model Selection of the Determinants of the Decision and of the Level of Patenting in UK Manufacturing[a,b]

Covariates	(1)		(2)		(3)	
	Decision	Count	Decision	Count	Decision	Count
% Sci./Eng. Staff	-0.006	0.024**				
	(0.009)	(0.010)				
Sales (Log)	-0.288***	0.387***	-0.238***	0.435***	-0.239**	0.427***
	(0.101)	(0.067)	(0.089)	(0.060)	(0.094)	(0.058)
Novel Product	-2.225***	0.305	-2.356***	0.462*	-2.401***	0.472*
	(0.651)	(0.272)	(0.711)	(0.270)	(0.745)	(0.266)
National market[c]	-0.805	1.133**	-0.554	1.352**	-0.578	1.347***
	(0.569)	(0.563)	(0.551)	(0.525)	(0.541)	(0.512)
Intl. market[c]	-1.095*	2.012***	-0.893	2.293***	-0.938	2.260***
	(0.648)	(0.615)	(0.598)	(0.552)	(0.587)	(0.539)
Gov. Support	-0.085	-0.171	-0.035	-0.123		
	(0.400)	(0.281)	(0.396)	(0.275)		
Univ. Partners.	-2.498**	0.380	-2.807**	0.509	-2.867**	0.447
	(1.215)	(0.379)	(1.365)	(0.357)	(1.409)	(0.332)
Complex	-0.773**	-0.276	-0.710**	-0.065	-0.735**	-0.080
	(0.300)	(0.301)	(0.290)	(0.297)	(0.287)	(0.298)
Constant	4.948***	-4.209***	4.253***	-4.848***	4.293***	-4.779***
	(0.831)	(0.779)	(0.767)	(0.748)	(0.776)	(0.727)
N	2414		2865		2902	
Non-zero obs.	316		354		359	
Ln α	1.389***		1.477***		1.495***	
Log-Likelihood	-1560.38		-1780.53		-1805.61	
Model Chi-square	118.49***		115.29***		117.04	
Pseudo R^2	0.144		0.144		0.144	
BIC	-15533.98		-19109.93		-19407.29	
AIC	1.309		1.255		1.255	
Vuong test	4.76***		5.25***		5.24***	
LR test	3016.18***		4197.63***		4236.04***	

[a] Robust standard errors in parentheses.
[b] * significant at 10%; ** significant at 5%; *** significant at 1%.
[c] The reference markets are the local and regional ones.

[144] Likelihood ratio test was carried out for all variables but only government support was not significant ($\chi^2 = 0.21$, p=0.8984).

Outcome

The base specification model was then augmented by introducing our variables of interest, that is, the importance assigned to the mechanisms of appropriability. The results can be seen in Tables 10 and 11[145].

Table 10 - Appropriability Mechanisms and Patenting: Results from Zero-Inflated Negative Binomial Models[a,b]

Covariates	Conf. agreement		Secrecy		Copyright		Reg. of design	
	Decision	Count	Decision	Count	Decision	Count	Decision	Count
Sales (Log)	-0.058	0.428***	-0.147	0.413***	-0.147	0.413***	-0.130	0.427***
	(0.087)	(0.057)	(0.091)	(0.059)	(0.091)	(0.059)	(0.102)	(0.061)
Novel product	-2.033**	0.451*	-2.062***	0.377	-2.062***	0.377	-2.233***	0.402
	(0.971)	(0.235)	(0.672)	(0.246)	(0.672)	(0.246)	(0.585)	(0.251)
National market[c]	-0.219	1.269*	-0.833	1.169*	-0.833	1.169*	-0.665	0.973*
	(0.943)	(0.681)	(0.641)	(0.690)	(0.641)	(0.690)	(0.643)	(0.551)
Intl. market[c]	-0.290	1.966***	-0.979	2.011***	-0.979	2.011***	-0.998	1.730***
	(1.019)	(0.725)	(0.710)	(0.697)	(0.710)	(0.697)	(0.701)	(0.589)
Univ. partners.	-1.480***	0.408	-2.186***	0.479	-2.186***	0.479	-2.348***	0.572*
	(0.528)	(0.336)	(0.651)	(0.302)	(0.651)	(0.302)	(0.611)	(0.323)
Complex	-0.823**	-0.011	-0.871***	-0.113	-0.871***	-0.113	-0.689*	0.166
	(0.341)	(0.269)	(0.306)	(0.279)	(0.306)	(0.279)	(0.389)	(0.257)
Low import.[d]	**-2.150*** **	**-0.259**	**-1.531*** **	**0.479**	**-1.531*** **	**0.479**	**-2.107*** **	**0.210**
	(0.459)	**(0.413)**	**(0.475)**	**(0.341)**	**(0.475)**	**(0.341)**	**(0.600)**	**(0.350)**
Medium import.[d]	**-2.139*** **	**0.610**	**-2.095*** **	**0.885*** **	**-2.095*** **	**0.885*** **	**-3.045*** **	**0.362**
	(0.481)	**(0.390)**	**(0.653)**	**(0.327)**	**(0.653)**	**(0.327)**	**(0.982)**	**(0.372)**
High import.[d]	**-2.709*** **	**0.731* **	**-1.898*** **	**0.635** **	**-1.898*** **	**0.635** **	**-2.719*** **	**0.800** **
	(0.728)	**(0.419)**	**(0.631)**	**(0.308)**	**(0.631)**	**(0.308)**	**(0.796)**	**(0.331)**
Constant	3.531***	-5.091***	4.241***	-4.799***	4.241***	-4.799***	4.120***	-4.803***
	(0.999)	(0.896)	(0.907)	(0.867)	(0.907)	(0.867)	(0.967)	(0.713)
N	2501		2491		2471		2483	
Non-zero obs.	349		351		337		342	
Ln α	1.393***		1.534***		1.422***		1.425***	
Log-Likelihood	-1669.94		-1675.69		-1639.32		-1634.83	
Model Chi-square	141.72***		111.56***		114.87***		124.44***	
Pseudo R^2	0.171		0.170		0.162		0.175	
BIC	-16064.74		-15965.10		-15861.68		-15976.34	
AIC	1.352		1.362		1.344		1.334	
Vuong test	4.56***		4.15***		4.80***		4.67***	
LR test	3957.97***		4160.33***		3839.74***		3804.48***	

[a] Robust standard errors in parentheses.
[b] * significant at 10%; ** significant at 5%; *** significant at 1%.
[c] The reference markets are the local and regional ones.
[d] The baseline is the non-use of a mechanism.

145 Regarding the adequacy of the analytical framework, all models present both the Vuong and the likelihood-ratio tests significant. This means that the zero-inflate negative binomial model fits the patent applications distribution better than the negative binomial model and the zero-inflated Poisson model, respectively.

The picture that emerges from the estimations is that the importance of each mechanism is significant in the decision part but not necessarily in the count part. On the one hand, the use of each mechanism implies an increase in the likelihood that a firm applies for at least one patent. On the other hand, the count part reveals that few mechanisms are directly related to the number of patents. Overall, the estimation results are contrary to our initial hypotheses, at least the ones that relate to the probability of applying for patents (i.e., H8a, H9a, H10a, and H11a).

Table 11 - Appropriability Mechanisms and Patenting: Results from Zero-Inflated Negative Binomial Models[a,b]

Covariates	Trademark		Lead-time		Design complex.	
	Decision	Count	Decision	Count	Decision	Count
Sales (Log)	-0.054	0.462***	-0.129	0.453***	-0.105	0.462***
	(0.078)	(0.065)	(0.083)	(0.065)	(0.112)	(0.065)
Novel Product	-1.622***	0.376	-2.272***	0.413*	-2.565**	0.376
	(0.494)	(0.238)	(0.780)	(0.246)	(1.098)	(0.238)
National market[c]	-0.510	1.213	-0.237	1.303**	-0.338	1.213
	(0.649)	(0.792)	(0.764)	(0.562)	(1.201)	(0.792)
Intl. Market[c]	-0.708	2.007**	-0.456	2.171***	-0.371	2.007**
	(0.660)	(0.816)	(0.808)	(0.592)	(1.241)	(0.816)
Univ. Partners.	-1.948***	0.473	-2.587***	0.415	-2.225***	0.473
	(0.580)	(0.298)	(0.830)	(0.302)	(0.749)	(0.298)
Complex	-0.896***	-0.031	-0.685**	0.014	-0.628*	-0.031
	(0.281)	(0.251)	(0.316)	(0.249)	(0.328)	(0.251)
Low import.[d]	**-1.824*** **	**0.795** **	**-1.425*** **	**0.234**	**-1.645*** **	**0.795** **
	(0.449)	**(0.370)**	**(0.406)**	**(0.440)**	**(0.449)**	**(0.370)**
Medium import.[d]	**-2.549*** **	**0.693** **	**-2.071*** **	**0.109**	**-2.279*** **	**0.693** **
	(0.481)	**(0.313)**	**(0.452)**	**(0.374)**	**(0.462)**	**(0.313)**
High import.[d]	**-2.344*** **	**0.563* **	**-2.673*** **	**-0.009**	**-2.572*** **	**0.563* **
	(0.396)	**(0.338)**	**(0.570)**	**(0.339)**	**(0.910)**	**(0.338)**
Constant	3.699***	-5.552***	4.058***	-5.088***	3.628***	-5.552***
	(0.803)	(0.850)	(0.895)	(0.769)	(1.051)	(0.850)
N	2486		2505		2484	
Non-zero obs.	343		350		346	
Ln α	1.229***		1.504***		1.511***	
Log-Likelihood	-1631.19		-1700.63		-1671.36	
Model Chi-square	126.38***		129.52***		143.97***	
Pseudo R^2	0.179		0.156		0.163	
BIC	-16010.06		-16038.63		-15912.09	
AIC	1.329		1.375		1.363	
Vuong test	5.76***		5.47***		4.38***	
LR test	3872.43***		4086.83***		4065.84***	

[a] Robust standard errors in parentheses.
[b] * significant at 10%; ** significant at 5%; *** significant at 1%.
[c] The reference markets are the local and regional ones.
[d] The baseline is the non-use of a mechanism.

Secrecy is the mechanism upon which academic arguments are most disputed. A message from the findings is that firms that place more emphasis on secrecy (in the two forms studied here) are more likely to patent than the ones for whom secrecy does not matter. From the substitutability standpoint this is a striking finding because by suggesting that secrecy and patents are likely to be used together it challenges the concept that firms have to choose one or the other. Therefore hypotheses H8a and H8b do not stand on the basis of the findings of this study, and should be refuted.

The models accounting for intellectual property rights (i.e., copyright, design registration, and trademarks) indicate that hypotheses H9a and H9b can be rejected. An increasing degree of importance of each type of IPR is not necessarily conducive to a larger number of patent applications, but for those which copyright, registration of design or trademarks are highly important the probability they will apply for a larger number of patents is higher than for those who do not perceive these mechanisms important at all. The same applies for the decision as to whether or not apply for a patent. But in these models it seems that on a few occasions (mainly in the decision part) there is a limit of importance above which the likelihood that firms decide to apply for a patent starts to decline. This may indicate that for the firms that highly rate these mechanisms they are likely to be more important than patents. However, it seems that despite these mechanisms being more important than patents the latter is not ignored. Furthermore, no evidence is observed that firms that value other types of IPRs are less likely to apply for patents than firms that do not use copyright, design registration, and trademarks. It seems that those firms less likely to apply for patents are exactly the ones who do not use other types of IPRs either. This lends support to the complementary argument.

Lead-time is one of the mechanisms whose results seem puzzling at first glance because the decision part and the count part point in opposite directions. On the one hand, for those for whom lead-time is increasingly important, the probability of applying for one patent is higher than for those who disregard lead-time as a way to capture value from innovation. On the other hand, final patent numbers decrease as lead-time becomes more and more important. However, the non-significance (from the statistical standpoint) of the coefficients in the count part makes it difficult for the substitutability argument to prevail. Thus, hypotheses H10a and H10b cannot be sustained, and hence should be rejected.

The complexity of innovation provides results to a certain degree similar to the results of IPRs. That is, it is signalled that a higher importance of the complexity of the innovation may lead a firm to become more prone to patent. However, although firms that place some importance (low or medium) on complexity tend to apply for more patents than those for which complexity is not used, the same cannot be said for those who highly rate complexity. Again, one could be tempted to interpret these results as that an increase in the importance of complexity reduces the number of patents, and therefore they are substitutes. But this assertion cannot be made once there is a clear sign to the contrary in the decision part. Even if one concentrates only upon the count part of the model it is difficult to argue in favour of the substitutability line of thought because no negative (and statistically significant) impact is observed. Thus, hypotheses H11a and H11b should be refuted.

The findings presented above regarding the impacts of the appropriation methods on the decision to patent and the number of patents were supplemented by the overall intent firms described to have in protecting their knowledge assets. An initial attempt to capture firms' appropriation intent was made by using the 'stated appropriation intent' index described earlier in this chapter and in the previous chapter. The proxy used to represent appropriation intent does not include the importance given to patents, and it is deliberately assumed that patents and other mechanisms have equal weight in firms' appropriation strategies. In order to relax this assumption we let the data 'speak for itself' using a more scientific approach. The technique of factor analysis was also used to construct a variable (or variables, if applicable) representing the overall appropriation intent.

Table 12 - Factor Analysis of Mechanisms of Appropriability

Mechanism	Factor Loadings	Factor Loadings
Patent		0.75942
Conf. Agreement	0.78851	0.78753
Copyright	0.72072	0.72420
Design Registration	0.71805	0.74728
Trademark	0.71933	0.74004
Complexity of design	0.79195	0.77479
Lead-time	0.73910	0.72174
Secrecy	0.82847	0.81482

One of the purposes of the technique of factor analysis is to look for a 'simpler structure' by reducing the number of dimensions of analysis (Tacq 1997). Thus, we would be able to verify the way all mechanisms are related, and perhaps elaborate further on the substitutability/ complementary debate. Along the lines of the 'stated appropriation intent' index a first exercise was undertaken without accounting for the importance of patents. Following that, a second investigation was made, but now accounting for the importance of patents. In both cases just one factor was detected[146] (eigenvalue greater than one), and they could explain 99.23% and 97.58% of the variance, respectively (Table 12).

Table 13 - Appropriation Intent and Patenting: Results from Zero-Inflated Negative Binomial Models[a,b]

Covariates	(4)		(5)		(6)		(7)	
	Decision	Count	Decision	Count	Decision	Count	Decision	Count
Sales (Log)	-0.149	0.464***	-0.086	0.437***	-0.041	0.422***	-0.172**	0.419***
	(0.118)	(0.064)	(0.124)	(0.059)	(0.130)	(0.059)	(0.086)	(0.059)
Novel Product	-2.147***	0.560**	-2.253***	0.407*	-1.424**	0.401*	-2.362***	0.451*
	(0.698)	(0.262)	(0.708)	(0.234)	(0.619)	(0.224)	(0.720)	(0.256)
National Market[c]	-0.427	1.375**	-0.108	1.281**	0.105	1.181*	-0.705	1.203**
	(1.157)	(0.550)	(1.115)	(0.626)	(1.190)	(0.625)	(0.545)	(0.509)
Intl. Market[c]	-0.671	2.089***	-0.013	1.942***	0.117	1.735***	-0.886	2.096***
	(1.231)	(0.574)	(1.262)	(0.657)	(1.283)	(0.651)	(0.582)	(0.520)
Univ. Partners.	-1.925***	0.669**	-1.535**	0.623**	-0.775	0.638**	-2.730***	0.434
	(0.652)	(0.308)	(0.679)	(0.302)	(0.668)	(0.309)	(0.964)	(0.315)
Complex	-1.112**	0.291	-1.097**	0.128	-0.951**	0.159	-0.706**	-0.030
	(0.445)	(0.286)	(0.495)	(0.235)	(0.474)	(0.237)	(0.287)	(0.273)
Appr. Intent	**-14.85*** **	**0.904**	**-2.378*** **	**0.385** **	**-2.816*** **	**0.500*** **		
	(3.659)	**(0.770)**	**(0.479)**	**(0.157)**	**(0.410)**	**(0.180)**		
Strategy							**-1.081*** **	**0.249**
							(0.295)	**(0.322)**
Constant	5.457***	-5.737***	2.649**	-5.344***	2.257*	-5.209***	4.311***	-4.772***
	(1.472)	(0.992)	(1.196)	(0.748)	(1.366)	(0.724)	(0.795)	(0.733)
N	2436		2436		2433		2764	
Non-zero obs.	332		332		331		355	
Ln α	1.633***		1.577***		1.449***		1.505***	
Log-Likelihood	-1579.43		-1558.11		-1511.47		-1767.93	
Model Chi-square	128.26***		139.07***		142.90***		126.45***	
Pseudo R^2	0.182		0.193		0.215		0.147	
BIC	-15704.77		-15747.41		-15814.33		-18232.57	
AIC	1.311		1.293		1.256		1.292	
Vuong test	6.24***		4.39***		4.05***		5.03***	
LR test	4005.86***		3887.31***		3835.95***		3974.14***	

[a] Robust standard errors in parentheses.
[b] * significant at 10%; ** significant at 5%; *** significant at 1%.
[c] The reference markets are the local and regional ones.

[146] Although the simplest criterion is to retain factors with eigenvalues greater than one (Hutcheson & Sofroniou 1999), Tacq (1997) argues that this is not always appropriate. However, in this study that criterion was applicable because the factors retained could explain most of the variance.

The results from factor analysis indicate that not all mechanisms have the same weight in firms' appropriation strategies, although inter-mechanism differences are not large. Thus, perhaps the results from the estimations where factors are used (instead of the SAI index) shed more light on the relationship between patents and appropriation strategy than the results from the appropriation index. The factors were then incorporated in the regression models using model (3) from Table 9 as the base specification model. The estimates are reported in Table 13 (models (5) and (6), respectively).

According to the estimates of the model (4), the more importance firms give to appropriation the more likely it is that they will apply for a patent. However, that model indicates that once the decision is made, one cannot assert that higher appropriation intent means larger number of patent applications. Although in model (4) one would expect firms keener on appropriation to pursue patents more intensively, a few remarks should be addressed. Firstly, firms may use a range of protective devices rather than patents to seek appropriation of their innovations. So, even devoting a great deal of effort to appropriation a firm may not be interested in patents if other mechanisms are perceived more effective, especially if they are substitutes to patents. Secondly, the index (SAI) used does not incorporate the importance of patents. But this does not seem to be the real cause since one of the models using a factor from factor analysis did not take into account the importance of patents either. Finally, the index was built up assuming that all mechanisms have the same weight, and although the factor loadings (Table 12) are not far off they seem to contribute differently.

If in model (4) appropriation intent was not found to be related to the number of patents, this was not the case in models (5) and (6). The results from these models suggest that a higher interest in appropriation leads to a higher probability of deciding to apply for a patent, and, given that this decision is made, a higher number of patents is applied for. Therefore, we are driven to not reject hypotheses H12a and H12b.

We also took advantage of one particular question in the survey instrument to observe the patent-strategy relationship. Question 17 (item 1) asked whether firms have made any changes in their strategy to gain competitive advantage. More specifically, it was asked whether 'implementation of new or significantly changed corporate strategies (e.g., mission statement, market share)' has impacted on performance. The findings (model (7)) suggest that firms are becoming more inclined to align patenting decisions and strategy, though the number of patents was not found to be explained by changes in strategy. These results however should be interpreted in light of firms' overall innovativeness, as we shall see in the next section.

5.6 Discussion

The results presented earlier demonstrate the uneven impact of each individual mechanism. Regardless of the pattern observed across the mechanisms studied it is clear that the use of them do not make patents less likely to be pursued, though the extent those mechanisms are related to the level of patenting seems to be only marginal. The substitutability argument could be advocated if positive and statistically significant signs were found in the decision part, or if negative and statistically significant signs were found in the count part, but none of them were observed. An increase in the probability that a firm will apply for a patent when other mechanisms are used suggests that they are not substitutes in firms' appropriation strategies. Even the non-significance of many coefficients in the count part does not suggest that patents and other mechanisms are substitutes. It simply means that those who use other mechanisms and those who do not use them are likely to apply for the same number of patents, other things constant. Thus, the number of patents a firm applies for seems to be more dependent on its innovative capacity (other things constant) than on its strategic action (model (7)).

The negative trend observed in the count part of the model accounting for lead-time may be a result of, amongst other things, the rent streams that are quickly dissipated over time due to the pace of technological progress. One perhaps would expect that when lead-time is ranked very highly, patents do not matter much because a higher importance assigned to lead-time may be a sign of the high rate of obsolescence of the innovation. Thereby, the innovation would loose its value sooner and, therefore, the value of its corresponding patent(s) would follow such depreciation. This view may be reliant upon the assumption that speed is more important in industries where the rate of technological progress is faster, and hence patents would be neither useful nor efficient. This interpretation can be misleading though. Firstly, for we have seen that patents can be used as bargaining chips in these industries (Hall & Ziedonis 2001). Secondly, because lead-time advantage is pursued not only due to the rate of obsolescence of innovations but also due to firms' strategies as to be the leader in the market; having a head start over competitors may help in reaping the returns from innovation before someone else comes with an alternative to the existing innovation. In this case, patents can be of assistance in delaying the appearance of alternative innovations, and hence can help in extending lead-time benefits (Robinson 1998). Therefore, although our findings indicate that the level of patenting of those who rely upon lead-time is not higher than of those who are not reliant on this mechanism, the benefits accrued to a first-mover may increase as long as an isolating mechanism such as patents can be used concurrently. As we have found no strong evidence to support hypotheses H10a and H10b, they should be refuted.

Maybe the same sort of rationale can be applied when interpreting the results of innovations' design complexity. One could argue that the more complex an innovation is the more difficult it is to be imitated. Therefore, the related invention does not even need to be patented to be protected against others from copying, its design is its own 'protection'. This may be a naïve point of view though, but it is true that a firm operating at the frontier of knowledge and being able to master a cutting-edge technology can have a head start over late comers. However, a strategy of not patenting could only be viable if a firm could make sure that it has all other, or at least the main, complementary assets to commercialize the innovation (Teece 1986). Moreover, the innovator would have to assure that his/ her tacit knowledge would not be accessed by rivals, and this seems to be very costly (Liebeskind 1996) and perhaps impossible (Mansfield 1985). Therefore, despite it being well known that patents can be circumvented and most of the time they only provide limited effectiveness in protecting the returns from innovations (Granstrand 1999; Levin et al. 1987), the results suggest that any help in postponing competition is welcomed by firms, and patents, on average, seem to contribute on this. Nevertheless, the results indicate that the number of patents does not increase when complexity is highly ranked. As complexity could be interpreted as the number of commercialized parts of the final innovation, the complementary innovations are unlikely to be under the control of a single firm, and thus other firms may hold patents on certain parts of the final innovation. Hence a further effort to hold more patents could be counterproductive because at the end of the day the firm will not be the only one to appropriate the economic benefits from final innovation. It is true that these firms, as compared to those for which innovation is not so complex, have a further incentive to apply for patents since they are likely to use patents to bargain with other innovators (Hall & Ziedonis 2001) and to hold a large portfolio of patents to avoid litigation (Somaya 2003). So, these incentives to apply for more patents could be 'inflating' the coefficients and overshadowing the 'true' effect. However, as an industry dummy is employed in this estimation, this industry characteristic is supposed to be controlled for. It seems therefore that the results support the idea that patents enhance the degree of appropriability that the complexity of the innovation *per se* gives to firms, and thus hypotheses H11a and H11b should be rejected.

Intellectual property rights in the form of copyright, registration of design and trademarks were found to be correlated to patents and hypotheses H9a and H9b were thus rejected. Although the legal rationale may hold as to the suitability of each intellectual property to particular circumstances (i.e., output of intellectual activity), from a strategic point of view those mechanisms seem to complement each other with respect to the extent that appropriation will be derived from the innovative effort. Moreover, this may be evidence that economies of scale apply to those activities. The results for copyright could be disputed on the grounds that firms that place too much value on copyright might be those for which patents are not necessarily applicable to gain ownership over their innovations (e.g., literary works, computer programs). Nevertheless, this may not necessarily exclude patents from their portfolio of protective devices because innovation does not have to be restricted to the final product. Innovative firms may pursue innovation at various levels (e.g., technology, organisation, communication) and the process that produces the final product could well be an object of firms' innovativeness, and thus patented. Perhaps registration of designs and trademarks would be expected to be more closely related to patents than copyright. Registration of designs, for example, enables firms to exercise ownership over complementary inventions that might not be patentable but that might be of some value to the overall output delivered to customers. Thus, it can be expected that patents and registration of designs work hand-in-hand. Trademarks, in turn, may be helpful in the diffusion process. Whilst patents preclude others from commercializing a patented invention without the innovator's consent, trademarks help in disseminating that innovation and making the market aware of it; patents *per se* are unlikely to make the market buy innovations.

Patents and secrecy were found to a large extent to work as complements as opposed to substitutes. This may not reconcile with what the theoretical literature argues (Takalo 1998). That patent numbers are not negatively (and significantly) impacted by the use of secrecy suggests that the disclosure of technical information is not as serious a drawback to patent protection as was thought. Perhaps the inadequacies of secrecy (e.g., Liebeskind 1996; Mansfield 1985) and patents (e.g., Cohen et al. 2000; Duguet & Kabla 2000; Mansfield et al. 1981) are the driving forces behind their concurrent use; or their merits enable a synergy that enhance appropriability and therefore, whenever possible, they are explored at the same time (Graham 2003). Mansfield (1985) observed that information leaks out. And this may not necessarily be negative since it also leaks in. Thereby, in seeking for appropriating the returns from their innovative effort firms are expected not to rely only upon one mechanism to build up a tighter appropriation climate, though a mechanism can be more adequate than another under some circumstances. For example, depending on the appropriability regime where a firm operates, patents can be a strong or a weak protective device, and engineering around patents is likely to be the norm rather than the exception. But sometimes patents can be very effective in stopping others from introducing a competing alternative to the existing innovation. The complementary role between patents and secrecy can be a sign of the importance of tacit knowledge. If patents disclose the technical knowledge used to generate the innovation, they only enable rivals to have access to the codified part of this knowledge. As long as the tacit part of knowledge is kept by innovators they are likely to be able to have an advantage over rivals. Even if interpretation depends to a large extent on firms' absorptive capacity (Cohen & Levinthal 1990), codification is an inevitable part of the appropriation process, and the more it is codified the more likely it is to be undesirably accessed.

The extent, however, that firms will use patents and other mechanisms seems to be dependent on the degree of appropriability of the knowledge concerned. For example, the more mature a technology is the easier it is to be imitated. In other words, the degree of appropriability tends to fall over time because more agents become able to codify the innovators' tacit knowledge and transform this codified knowledge on their own tacit knowledge. Even if patents are not applied for, the process of codification is required because knowledge has to be communicated in order to be embodied into innovations. This means that sooner or later other agents will become able to interpret the tacit knowledge held by the innovator as long as they have access to its embodied form. Insofar as the number of agents able to interpret this knowledge increases alternative modes of appropriability must be sought (Saviotti 1998). For example, the control of complementary assets (e.g., brand name, distribution channels, switching costs, customer services) is an important element for firms to appropriate the rents from their innovations (Teece 1986). An increase in the returns can be expected if a firm controls, for instance, either the most important or the unique distribution channel. The questionnaire used in this research, however, has the limitation addressing only a single complementary asset (i.e., trademarks – interpreted as synonymous to brand).

As we were not able to examine all mechanisms of appropriability, we extrapolated the firms' emphasis on appropriation on the basis of the available mechanisms; we described that emphasis as 'appropriation intent'. We observed that hypotheses H12a (i.e., the higher the appropriation intent of a firm, the more likely a patent will be applied for) and H12b (i.e., the higher the appropriation intent of a firm, the higher the level of patenting, *ceteris paribus*) were not rejected by the evidence from the estimations where the variable 'appropriation intent' was derived from factor analysis. Although hypothesis H12b seemed to be falsified by the initial evidence (on the basis of the SAI index), we noticed that it was a matter of 'refinement' of the variable.

Anton & Yao (2004) are perhaps the pioneers in modelling competition assuming that a mixture of patents and secrecy can be used as opposed to one or the other. Although they assume that the decision as to how patents and secrecy will be employed depends on how much knowledge will be disclosed, we conjecture that the approach should be slightly different. One reason is that even if the knowledge is broadly disclosed its codification may not be immediate. Other firms may not hold the skills (Cohen & Levinthal 1990) or the assets (Teece 1986) to transform the codified knowledge based on their own knowledge (either by imitating or by developing a competing alternative). Another reason is that knowledge disclosure does not seem to be a serious downside of the patent system, though this needs to be further confirmed (as we shall see in the next chapter). One implication of our results is that economic theory should go further and not restrict the analysis to patents and secrecy only. We suspect that the approach should be how much knowledge can be appropriated, and thus the role of patents in firms' appropriation strategies should be modelled. The extent that knowledge can be appropriated, however, is not affected only by how much of this knowledge will be available to competitors (e.g., control of complementary assets).

We also investigated the relationship between patenting activity and strategy. The findings suggest that firms that changed their strategy over the period 1990-2000 became more inclined to apply for a patent, compared to their counterparts that did not go through that change. In the previous section, however, we stressed that one should be cautious in interpreting these results because they could be misleading. We suspect that such finding is likely to derive from innovation contagion, that is, innovativeness is not concentrated simply on technology-related issues; it spans over the various functions of an organisation. So, firms that are innovative at one level are likely to be innovative at other levels. We conjecture therefore that the most innovative firms are likely to change their strategies over time, and thus the results may be mirroring their innovative profile rather than the patent-strategy relationship.

Therefore, this evidence is not robust enough not even to tentatively conclude that intangibles are becoming increasingly important (Lev 2001; Teece 1998), or that we might be moving 'towards intellectual capitalism' (Granstrand 1999). Let alone to conclude that a pro-patent era observed for the US (Kortum & Lerner 1999) has also come into effect for the UK. On this further research is needed.

5.7 CONCLUSIONS

Although appropriation of rent streams may not be the most important element to assure competitive advantage, it might be central to firms. If firms are not able to appropriate enough returns from their innovations they will not be able to, at least, sustain themselves in the market, let alone to outperform competitors. Therefore, it is in our interest to advance the understanding on how firms co-ordinate their activities for the purpose of appropriating the returns from their innovative effort.

Using firm level data from the third Community Innovation Survey carried out in the UK this chapter looks at how patents and other mechanisms of appropriability are correlated. We argue that firms' decisions to patent are not only a result of their own innovative capacity. There are, we think, strategic decisions as to whether patents should be used that rest with the way firms choose to appropriate the benefits from their innovations. This may determine whether or not a patent will be pursued. Our analyses employ zero-inflated negative binomial models in order to examine how appropriation intent and the perception of the importance of appropriation mechanisms impact on the decision to patent and level of patenting. On the basis of the results detailed above the following messages are delivered.

Firstly, in looking at firms' perception of the importance of appropriability mechanisms we observed that a perceived higher importance of those mechanisms positively impacts on the decision of applying for a patent. Although such perception impacts to a much lesser degree when it comes to total patent numbers, there was not found any negative and significant impact that would support the substitutability hypothesis. It seems therefore that the level of patenting has more to do with firms' innovative capacity than with their strategic behaviour. Secondly, appropriation intent, according to our metrics, seems to be correlated to firms' patenting behaviour. It is shown that the decision to patent and the level of patenting are determined by the emphasis firms place on appropriation. These reinforce that patents and other mechanisms are more likely to work as complements rather than substitutes in firms' appropriation strategies. Finally, the results suggest that innovativeness is not concentrated only on technology-related issues; it may span over the various functions of an organisation, including strategy.

Taken as a whole, the results seem to support earlier empirical evidence on the complementary role of patents. Based upon an econometric framework that accounts for some properties of the response variable, and upon a number of mechanisms and industrial sectors, the findings of our investigation have contributed to advance our existing knowledge on whether patents interact with other mechanisms. Nevertheless, our study presents limitations that should be borne in mind, needless to say the limitations of survey-based studies. A clear limitation is that appropriation strategies may be a result of so many factors that no single empirical work can explicitly control for them all, and thus further empirical research is needed. Moreover, this study does not establish any link between the ways firms pursue appropriability and their performance. Furthermore, as the importance of the mechanisms of appropriability may vary throughout the innovation process, our approach may not capture the exact way they interact. Clearly, much else remains to be learned but these are just a few avenues of research that merit further attention.

Despite the limitations, our findings have implications that should be addressed. One theoretical implication is that in examining appropriability conditions the degree that the knowledge can be appropriated should be incorporated. Assuming, for example, that the knowledge that is patented is the same that is kept secret can be misleading because it implies that resources are wasted if the two methods are used simultaneously. Even if the knowledge is the same, it might be in firms' interest to avoid rivals' opportunistic behaviour. As no method of appropriation is perfect, appropriability conditions are likely to be enhanced if firms know which mechanisms should be used and when. We have seen from the results above that, in general, patents and other appropriation mechanisms are used concurrently.

One managerial implication is that attention should be drawn to mechanisms of appropriability as a whole, although this does not mean that all of them have to be used. But because they seem to collectively strengthen the extent that firms are able to reap the benefits from their innovations, the effort devoted to each of the mechanisms has to be in line with the degree of appropriability sought and with the degree of appropriability that is feasible. As the effectiveness of each mechanism may be a result of existing regimes of appropriability peculiar to each industry, it might be valuable to assess industry structure and nature of knowledge before delineating an appropriation strategy.

CHAPTER 6

LOG BOOK OF A NEW SURVEY OF THE USE OF PATENTS IN UK MANUFACTURING

6.1 INTRODUCTION

Although in general the results are the most important part of a survey, the quality of the results is heavily dependent on the way the survey is designed and administered. A lot of attention needs to be devoted to the whole process of data collection (from survey design to data imputation) in order to minimize survey errors and, as a consequence, to make the results more reliable and valid. This chapter thus reports how a new survey of the use of patents in UK manufacturing was designed and administered.

The next section describes how the surveyed sample was chosen. The third section gives details about the design of the survey instrument. Then, the data collection process is explained in section four. Section five reports the procedures adopted to overcome problems with the data collected and not collected (non-responses). The sixth section presents the extent that inferences from this survey are reliable and valid. The last section concludes.

6.2 SAMPLING

One of the first steps to address in designing a survey is the target population. If the population is large the researcher will be unable to collect all the information he wants from all elements and thus a subset of the population will often be surveyed. The decision to be made is which part of the population to sample.

The purpose of sampling is to make statistically valid inferences for the population on the basis of only a small part of it (Fowler 1993). But in using only a fraction of the population there is a risk of population characteristics being distorted so that the sample survey may not represent the population properly, and inferences derived from it may not be valid. The objective is to end up with a sample that is representative of the population. However, there are no strict parameters upon which an assessment can be made as to the representativeness of a sample. As observed by Henry (1998:102), "[t]he labelling of a sample as representative reflects a subjective judgement of the writer, no more and no less".

Generally speaking, there are two major types of samples that can be achieved: probability and non-probability samples. The probability sample, is characterised by each member of the population having a known (and non-zero) chance of being selected as part of the sample. The vast literature[147] on survey methods favours the probability sample as it is built on a sounder theoretical foundation which also allows the determination of the appropriate size of the sample to be studied (Moser & Kalton 1993). Fowler (1998) observes that, in practice, a balance has to be struck between value (i.e., precision of the inferences) and cost. As stated by Moser & Kalton (1993:151), "(...) in many social research surveys, the desired size is unattainable in any case, because of financial, time, or personnel limitations. (...) [L]imitations imposed by a shortage of resources [have] to attain the highest precision possible by statistical ingenuity in the design". An assessment of whether a sampling design is appropriate or not depends on the purposes of the results, and on the resources available (Sudman 1983). The challenge, as stated by Henry (1998), lies in reducing total error, bearing study goals and resources in mind, as well as an awareness that errors cannot be eliminated entirely. This, however, does not mean that quality should be ignored during the sampling process by simply labelling the research as exploratory[148].

In order to comply with the requirements of a 'good' sample, close attention here was paid to the literature. But if we were to define the target population as all firms in UK manufacturing that hold patents it would have been impossible, at least with the resources and time available, to identify all firms in that sample, let alone their characteristics. As a result, we were compelled to use a non-probability sample. However, if we restrict our true population to the survey population, as advised by Kalton (1983), our results could perhaps be read as if derived from a probability sample (according to the author this is often done in the face of practical constraints, such as non-availability of information about the true population).

The best sampling frame we could find was a list of firms (list frame) that reported to have had costs of R&D. This list, also known as the UK *R&D Scoreboard,* is produced yearly by the UK Department of Trade and Industry. It contains information on R&D investment, capital expenditure (Capex), sales, profits, employee numbers, and growth of these quantities for UK and

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[147] Biemer & Lyberg (2004); Salant & Dillman (1994); Fowler (1993); Kalton (1983); Moser & Kalton (1993).

[148] Sudman (1983) asserts that many PhD students do so merely to protect their research from criticism against poor sample design.

international firms, and the information is extracted directly from firms' annual reports and accounts. Firms are classified by FTSE sector and by country. Although the UK *R&D Scoreboard* contains data on international firms, they are outside the scope of this research and therefore not covered in the analysis, which is restricted to firms operating in UK manufacturing industry (though they do not have to be domestically owned firms). In its current version (i.e., 2004) the scoreboard contains 700 UK firms and 700 international firms. This research made use of the UK *R&D Scoreboard* 2001 which comprised 597 UK-based firms, 343 of which were classified as in manufacturing (according to the classification used by the scoreboard).

We chose to use the R&D Scoreboard because, as suggested by the literature and confirmed by the results of previous chapters, the most innovative firms are those most likely to make use of patents. Moreover, we do not expect the target population to be much larger than the firms included in the UK *R&D Scoreboard*. The results from the Community Innovation Survey presented in previous chapters have shown that from a sample of 3440 firms, only 370 reported to have applied for at least one patent during the period 1998-2000, whereas 420 had used patents during the same period. Although it might be said that the generalisation of our results might be compromised by this sample frame, we do not think in the circumstances that this will be to any great degree. To avoid extrapolating the results too much and making them less precise Moser & Kalton (1993) suggest analysing the data bearing the survey population (UK *R&D Scoreboard*) in mind rather than the target one.

Despite the theoretical weakness of non-probability samples, their use is widespread and there are various methods of obtaining them (Fowler 1993; Kalton 1983). The sample frame of this research fits into the purposive category (also known as judgement or expert choice), which on some occasions can be more useful than a random sample (Biemer & Lyberg 2004). Nevertheless, in the absence of a more adequate list frame, the best we could do was to minimise the problems that arise when lists of this kind are used. Moser & Kalton (1993) indicate a few of them, such as i) elements that should be in the frame but are not (missing elements), and ii) elements that are in the frame but should not be (foreign elements). Although this is not a correction for bias produced by sampling procedure, the survey population will be better delimitated if we check for such problems. However, amendments to the list frame were only possible on the basis of the full coverage of the UK *R&D Scoreboard*.

As our target population is firms in UK manufacturing, the scoreboard firms were investigated to see whether[149] firms were correctly allocated in the scoreboard to the manufacturing sector or not. This led to an increase in the survey population from 343 to 414 firms. However, we then excluded the pharmaceutical firms interviewed in the beginning of this research because they were the sample selected to pilot test the questionnaire. In addition 13 other companies were found to be duplicates or else not in operation (insolvency or in liquidation), and hence were not included in the final survey population. The final list then comprised 395 firms. As the population was relatively small full coverage could be justified and questionnaires were sent to all of them. The final sample was to a certain degree randomly selected and thus more suitable for analysis using statistical tools.

For the sake of clarity Table 14 reports the number of firms surveyed in various industrial sectors of the UK *R&D Scoreboard*. As mentioned earlier, there were some firms that in principle would not be classified as in manufacturing if the classification of the Scoreboard was used. However, a closer look at their operations confirmed economic activity being derived from manufacturing processes, and hence they were included in our survey population.

Table 14- UK *R&D Scoreboard*: Number of Firms by Industrial Sector

Sector	Firms	Sector	Firms
Aerospace & Defence	11	Household Goods	18
Automobiles	15	IT Hardware	37
Beverages	4	Media & Photography	4
Chemicals	37	Oil & Gas	5
Construction & Building	13	Packaging	5
Diversified Industrials	2	Personal Care	7
Electronic & Electrical	51	Pharmaceuticals	52
Engineering & Machinery	67	Software & IT Service	13
Food Processors	20	Steel & Metals	4
Forestry & Papers	3	Support Services	1
Health	25	Tobacco	1
Total			**395**

[149] Using both the internet and the Financial Analysis Made Easy (FAME) database.

6.3 Questionnaire Design

After defining the survey population, the next step was the development of an instrument with which information would be collected. Survey instruments are key components of the measurement process and often mentioned as one of the sources of errors. As the decision was to carry out a postal survey, the data collection form would be completed by the respondent in the absence of the researcher. Thus a considerable amount of time was dedicated to its design.

Questionnaires are designed in order to meet the objectives of the research. To this end, the most complete and accurate information as possible should be gathered given the limited time and resources. The vast literature on survey methods offers several guidelines about the construction of data collection forms. These guidelines encompass issues such as i) content, ii) structure, iii) order, iv) wording, v) layout, vi) pre-test, and so on. We attempted to a large extent to follow those guidelines, especially those from Salant & Dillman (1994), Foddy (1993), and Converse & Presser (1986). However, as observed by Sheatsley (1983:200) "[u]nlike sampling and data processing, questionnaire design is not a science or technology but remains an art".

The questionnaire was constructed bearing the objectives of the research in mind and of course the literature review. Therefore, the focus of the survey was upon the use of patents, that is, how firms' patent portfolios are built, concentrating on four key questions: i) why, ii) what, iii) when, and iv) where to patent. Questions relating to information that could be easily obtained from secondary sources (e.g., R&D expenses) were not asked. The content of the survey instrument was supported to a certain degree by previous questionnaires [150] administered by Pitkethly (2001), Cohen et al. (2000), Granstrand (1999), Levin et al. (1987) and Taylor & Silberston (1973). Despite differences in scope, those previous studies could be thought of as overlapping with ours. This helped the researcher to have an idea about the length of previous questionnaires, their structure, contents, and layout.

The first decision as to format of the questionnaire concerned the type of questions to be asked. Open-ended questions were restricted to a minimum to help both the respondents in filling in the questionnaire and the researcher in coding the responses (Salant & Dillman 1994). Closed-questions were mostly interval and ordinal scaled. Question variety was also introduced to avoid a tedious filling-in process (Aldridge & Levine 2001). Although the questions did not have a 'don't know' option for lack of space, respondents were instructed in the very beginning to leave questions blank if they did not know the answer, or to write 'N/A' to indicate that the question did not apply to their firm.

The questionnaire was divided into 4 sections and, whenever possible, columns were employed to use the space of the paper more efficiently. Straightforward questions were asked both in the beginning and end of the questionnaire, with more complex questions in the middle. Question

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[150] The researcher is particularly grateful to Professors Richard Levin and Wesley Cohen, and Dr Robert Pitkethly by kindly providing the survey instruments used in their investigations.

numbering used letters and numbers, and questions were printed in both sides of paper to minimise instrument-length effects on the decision to take part in the survey. The extent to which the length of questionnaires negatively affects the response-rate is disputed, despite the immediate intuition that shorter-questionnaires are more likely to generate responses. We relied on previous questionnaires of this kind to determine the length of ours.

In addition, the layout of the cover page was carefully examined to make clear to addressees what the survey was about and who was administering it. The front page also contained a statement of confidentiality and a code number for data processing purposes. The cover page was printed on orange paper to attract the attention of the respondent and differentiate the questionnaire from other documents. The objectives of the research were highlighted (*italics*) overleaf as well as the confidentiality that would be given to individual responses. The back of the cover page also contained the directions for the completion of the data collection form, and the address to which it should be returned, though stamped return envelopes were also provided.

Scaling was another issue to which attention was given. Firstly, non-dichotomous questions were mostly employed for they allow the measurement of the strength of attributes (or attitudes). Secondly, Likert-type scales were favoured for their ease of formulation and interpretation. Thirdly, some decisions regarding middle alternatives were made. Survey researchers do not entirely agree whether or not middle points should be included in scales (Converse & Presser 1986). On the one hand, middle categories represent a neutral position and respondents under time constraints can feel more comfortable in choosing this, which would bias the results. On the other hand, the lack of a middle option forces respondents to choose to which side of neutral they belong, though this is no guarantee that the results would not be biased because the actual response should be the absent middle point (Moser & Kalton 1993). The decision was to elaborate a survey instrument where no middle category would be provided. It was based on what previous questionnaires had used. All of those provided a middle alternative. We took the alternative way because in most questions of our survey instrument the scale would refer to percentage intervals and middle points would not represent a neutral position.

Fourthly, it was decided to use six points in the response scale. The vast literature on survey methods suggests scales between five and seven (Foddy 1993). As there was to be no centre point, six was the natural outcome. Finally, the way intensity would be measured was chosen. Rating scales of the type 'strongly disagree/ strongly agree' are very sensitive to error because of the underlying assumption that respondents interpret intensity in the same way; there is no guarantee that when a respondent 'agrees' with something the intensity of her statement is lower than another respondent who replied 'strongly agree'. We thus kept the use of such scales to a minimum. Only a few questions used this labelling, and when used the suggestions by Foddy (1993) were followed, in particular the one that instructs one to allow respondents to look over the whole range of items before responding to each one. Converse &

Presser (1986) suggest the use of forced-choice questions, which we did to some extent by asking respondents the proportions applicable to particular items. This scale was also employed by Cohen and collaborators (2000). As they used a five-point scale, in contrast to ours that used six, the categories were slightly different. The six categories employed were i) less than 10%, ii) between 10 and 30%, iii) between 31 and 50%, iv) between 51 and 70%, v) between 71 and 90%, and vi) more than 90%.

Several drafts of the questionnaire were prepared and discussed with both supervisor and colleagues before a version to be pre-tested was produced. The questionnaire was piloted amongst the pharmaceutical firms that had been interviewed, though not all of them took part mainly because of shortage of time (three out of six participated in the pilot stage). They provided a few comments[151] that helped to refine the survey instrument up to its final version, which consisted of 47 questions, plus a back page where comments on patent activities could be addressed. A copy of the final version of the questionnaire is provided in Appendix 7.

6.4 DATA COLLECTION PROCESS

After selecting the 395 firms that would take part in the survey (survey population), addresses were collected using either the FAME database or the internet. During the preparation of the survey instrument, a few attempts were made to detect the right informant within companies by telephone. This was not successful mainly because those who answered our calls did not know to whom we should send our questionnaire. As for most companies the names of their directors were available on the FAME database, they were used as an intermediary contact as opposed to contacting the 'right' informant directly by telephone.

The mailing process was supposed to be initiated soon after the final survey instrument was ready for application. However, as this was in the very end of 2002 during the Christmas period, the decision was taken to postpone the mailing process to the beginning of 2003 in order to minimise non-responses[152]. Meanwhile, searches of the names of technical directors (or equivalent) were carried out over the internet. For those whose names were not available on the web the names from the FAME database were kept as our initial point of contact. On the basis of a list of addressees produced, an introductory letter (Appendix 8) was sent to explain the purposes and importance of the research project as well as to request assistance. Given the uncertainty as to the scope of responsibilities of the initial addressee, emphasis was placed upon whom the informant should be, and a request was made to pass the questionnaire, if necessary, to whoever was in charge of patenting issues within the firm.

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[151] Due to the small number of firms in the pilot stage no aggregate analysis of the responses was undertaken.

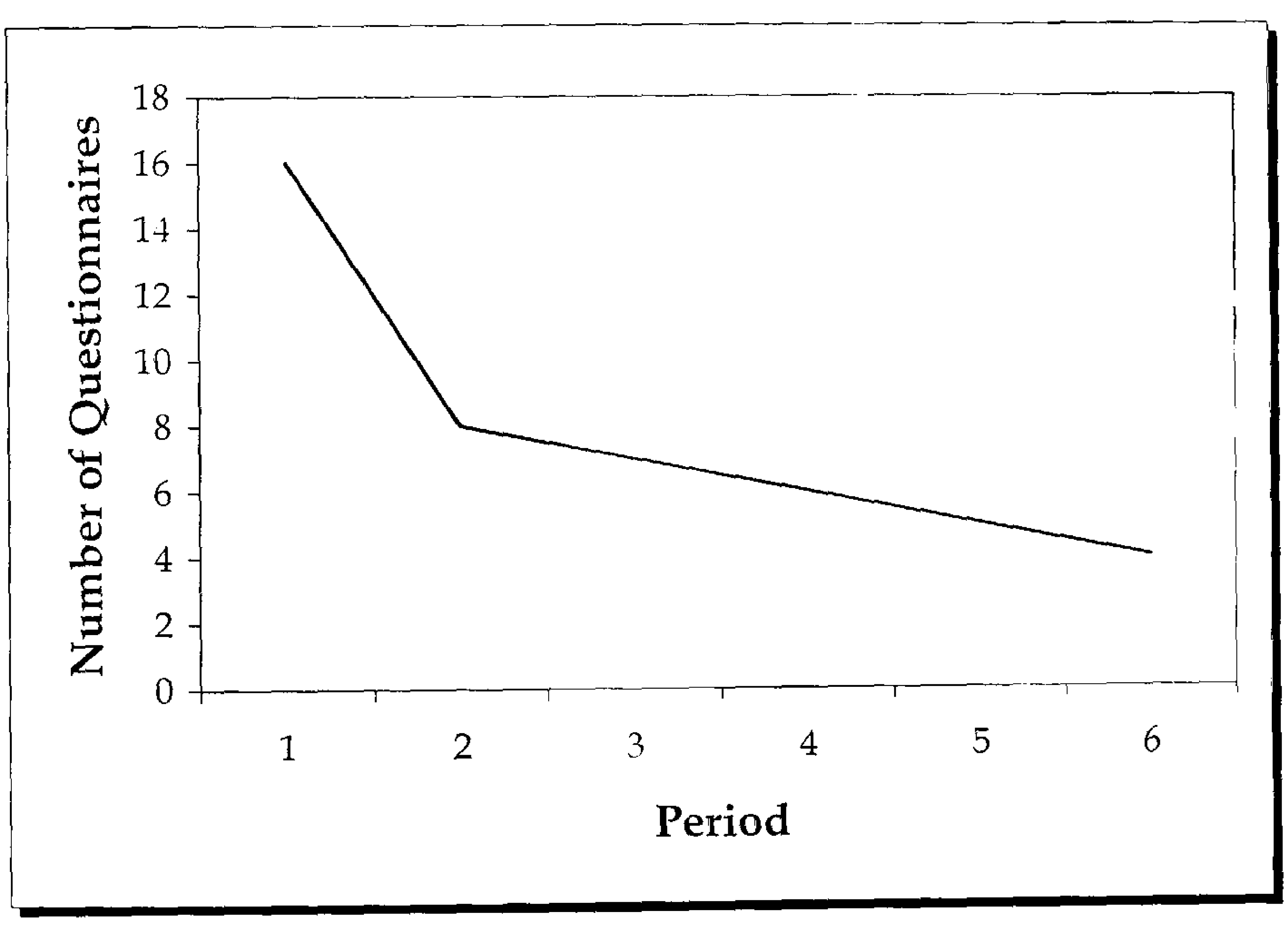
[152] In western culture it is expected that people are overloaded with work during the end of calendar years and perhaps this could increase non-response rates.

Seven firms declined our request within the first week of receipt of the introductory letter, and after this period the first mailing of questionnaires was sent. Both the questionnaire and a cover letter (Appendix 9) were mailed at that time. Twenty five questionnaires were returned because of either wrong address or a non existent addressee. Three weeks later 29 responses had been received, 13 of which declined to participate in the survey.

At the end of the third week a follow-up letter was sent (Appendix 10). Then, 34 responses were received over the next three weeks, but only eight questionnaires returned. So, after six weeks the first round of mailing was over and 24 usable questionnaires had been returned. A second round of questionnaires and follow-ups were administered over the following six weeks as an extra effort to increase the rate of return. In the mean time, the correct addresses (or names) of the 25 questionnaires returned were sought, and they were mailed again. The outcome of the second round was thirty nine responses, 23 in the second mailing of the questionnaire and 16 during the second mailing of the follow-up letter. However, only 13 questionnaires were filled in and therefore usable.

A further attempt to increase the rate of return was made by an invitation to join an online version of the questionnaire. The latest version was developed with assistance from the Information Systems Support Unit (ISSU) of the Warwick Business School. Vehovar et al. (2002) observe that web surveys are a recent phenomenon and, as such, knowledge on several aspects is still obscure (e.g., design, solicitation strategies). Despite the limited knowledge on the topic this was the only alternative available to us, as phone calls proved not to be very useful in this case. The wording of the online questionnaire was exactly the same as the paper one, though design was different for technical reasons. To avoid interference of extraneous participants, each firm received a password and a username to have access to the questionnaire. Nevertheless, due to legal aspects on confidentiality, the names of informants would not be disclosed to the researcher, unless volunteered. Despite this extra effort the rate of return was only marginally increased. Nine questionnaires were filled online, with only one informant identifying herself.

Figure 2 - Pattern of Responses to the Patent Survey



At the end of six months of data collection (from February to August 2003) the rate of return presented a stationary pattern (Figure 2). Therefore, no further effort was made to collect more information. Forty six usable questionnaires were obtained, seventy two negative responses were received, and seventeen firms were not reached (returned mails). A total of 118 replies were received out of 395 contacts attempted, for which 46 questionnaires were classified as usable, which corresponds to an effective response rate of 12% (Table 15).

Table 15 – Patent Survey Response Profile

(a) Survey population	395
(b) Not reachable contacts	17
(c) Eligible reporting units (a)-(b)	378
(d) Total replies	118
(e) Response rate (d)/(c)	31%
(f) Responding eligible units	46
(g) Adjusted response rate (f)/(c)	12%

The response rate can be considered low but the survey literature recognises that business surveys are amongst those most likely to produce lower response rates, and university survey researchers appear to suffer from even higher non-response rates (Willimack et al. 2002). Table 16 presents various reasons that firms reported as to why they did not take part in the patent survey.

Table 16 – Reasons Not to Take Part in the Patent Survey

Reason	No.
Not involved in patent activity	19
Work commitments	12
Survey not relevant	11
Do not have proper personnel to respond	10
Policy not to participate in surveys	10
Confidentiality issues	5
Mergers/ Acquisitions	4
Not manufacturing	1
Total	72

It could be that the data collection instrument was too long, though its length mirrored previous questionnaires. Moreover, it is not clear yet the extent that long questionnaires harm response rates (Salant & Dillman 1994; Dillman 1983). But it is fair to say that this problem was reported by Pitkethly (1995) in surveying British firms. He initially achieved an 11% return rate for British firms (as compared to 44% for Japanese firms), but that was boosted to 33% after shortening the questionnaire to one page. That strategy was not followed in the current research because it would inevitably lead to a huge loss of information.

The sample drawn from the UK *R&D Scoreboard* has the profile described in Table 17. The average R&D intensity (R&D per total sales) of the manufacturing firms on the Scoreboard is 22.6%. The sample has a higher average R&D intensity: 48.5%. If these figures are re-calculated for both population and sample but excluding firms whose R&D expenses are higher than sales, the proportions decrease to 6.5% and 7.2%, respectively.

Table 17 – Profile of the Scoreboard and Sample Firms

	source[a,b]	mean	se	median	min	max
R&D/ sales (%)	Scoreboard (379)	22.60	4.31	2.06	0.004	803
	Sample (37)	48.50	22.47	4.25	0.26	620
R&D (£ M)	Scoreboard (395)	32.57	9.07	2.8	0.02	2526
	Sample (38)	35.13	12.80	5.05	0.28	371
Sales (£ M)	Scoreboard (390)	1339	378	116.5	0	99843
	Sample (38)	3639	2610	70.5	0	99118
Profit (£ M)	Scoreboard (387)	152	57	5	-1113	16678
	Sample (37)	348	335	4	-1113	12328
R&D/ emp. (£ 000's)	Scoreboard (386)	14.11	1.76	2.7	0.1	433.3
	Sample (37)	22.01	7.76	5.5	0.2	231.1

[a] Population/ sample size between parentheses.
[b] Values from the online round of the patent survey not computed.

The average size of the sample firms is 8305 employees. The industrial sectors with the largest number of participants are pharmaceuticals, and engineering and machinery (15.22% each). For confidentiality reasons we cannot display the results in a very disaggregated form. Thus, we have grouped them according to a classification already used elsewhere in this thesis, that is, between 'complex' industries and 'discrete' industries which takes into account the number of patentable elements held by new commercialized products or processes (the categorisation may vary slightly from the one previously used because here it was not based on the UK SIC 92). Sectors assigned to complex industries were: aerospace, automobiles, construction and building, diversified industrials, electronic and electrical, engineering and machinery, health, household goods, IT hardware, media and photography, software and IT services, and support services. In turn, beverages, chemicals, food processors, forestry and papers, oil and gas, packaging, personal care, pharmaceuticals, steel and metals, and tobacco were assigned to the discrete category. This yielded the distribution shown in Table 18.

Table 18 – Distribution of Firms According to Aggregate Industry

	Scoreboard	Sample
Complex	64%	57%
Discrete	36%	43%

In the questionnaire respondents were asked to identify the industry where their R&D activities applied most (Q.A5), and also to provide examples of the output of those activities (Q.A6). That information enabled the further refinement of the allocation of firms to complex and discrete industries. The response sample was finally considered to 52% in the complex industry and 48% in the discrete industry.

About 32% of the *R&D Scoreboard* firms were considered to be small and medium sized (less than 250 employees). The final sample comprises a smaller share of small and medium sized firms: 27%. The distribution by size band and by type of industry can be seen in Table 19. Note that the two categories are independent, that is, in examining industry differences one should not be concerned about size differences because the null hypothesis of independence could not be rejected at 5% either by Pearson chi-square (chi^2 =11.14 [6 d.f.], p=0.084) or by Fisher's exact test (p=0.070)[153].

Table 19 - Share Distribution of Firms by Industry and Size Band

Size band	Complex (%)	Discrete (%)	Total (%)
< 50	Nil	25	11
50-249	9	25	16
250-499	24	6	16
500-999	5	Nil	3
1000-4999	38	19	30
5000-19999	19	13	16
> 19999	5	12	8
Total	100	100	100

6.5 DATA CLEANING & NON-RESPONSES

As soon as the questionnaires started arriving a code book was created in order to prepare for the input of the answers into a computer. Closed-ended questions constituted the greater part of the questionnaire, and thus a coding scheme could be done *a priori* without waiting for the end of the data collection process. Open-ended questions were mainly numerical, which also facilitated the creation of a coding scheme for them. Whenever they were not numbers, they were either names of countries or a description of the output of R&D activities. They were entered in the computer as responded but the former were

[153] Sheskin (2004) recommends the use of Fisher's exact test when the sample is small and the table may contain cells with low expected frequencies.

re-coded later. Data were transcribed manually to a computer by the researcher, with non-responses to questions/ items considered as missing and no values assigned to them.

In order to permit the running of statistical programs the dataset had to be cleaned, or at least adjusted. The major problem found during the input process regarded country-specific items. On a few occasions, when open-ended questions asked for the names of countries, respondents answered with a mix of individual countries (as requested) with regions (e.g., European Union, rest of the world) or continents. Countries received proper codes to make them distinguishable whereas regions/ continents were categorized as 'Other', and coded accordingly. With respect to 'numbers' (e.g., number of countries designated when using PCT) a few informants wrote 'ALL' to refer to the maximum number of countries possible under that particular circumstance. This was converted to '100' and '20' when referring to PCT and EPO member countries, respectively[154].

The editing process also enabled one to detect non-response in various questions. Item non-response is sometimes considered more serious than unit non-response (King et al. 2001). Missing data can bias the outcome of statistical results if it is correlated with the outcome of interest (Little & Rubin 1987). Both statistics and survey literature[155] have devoted some time to non-response, and

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[154] These figures are not exact as of today. They were rounded down because a few countries have become state-members after the survey instrument was administered (2003 relating to 2002).

[155] See for example Groves et al. (2002), King et al. (2001), and Schafer (1997).

as a result some techniques have developed over the years, such as the modelling of missing values and the use of single or multiple imputations. This study, however, approaches this issue in the most traditional way, which the majority of survey studies also rely upon, which is by not accounting missing data - also known as listwise (or case) deletion. The rationale is that "[t]he only real cure for missing data is to not have any" (Anderson et al. 1983:480).

Exceptions to the above approach were the questions whose response scale was in the percentage (%) format, but only in cases where at least one item of the question had been responded. In cases where questions were left completely 'blank', no assumption was made and data were coded 'missing', that is, no value was attributed to them. The rationale for our approach to missing data in those questions where at least one item was answered comes from the four most likely reasons that could have caused that event, though the decision process is far more complicated (Beatty & Herrmann 2002). Firstly, the respondent did not know the answer. Secondly, the item did not apply to the firm. Thirdly, the respondent did not want to answer (confidential information). Finally, the answer was zero percentage and the informant did not feel comfortable with the scale 'less than 10%' to represent it.

Insofar as the respondent answered at least one item of the question, confidentiality should not be the problem and she would be willing to collaborate. Moreover, the guidelines in the beginning of the questionnaire explicitly asked the respondent to write 'N/A' beside the corresponding question/ item if it was not applicable. Further, although the willingness to collaborate of the respondents may have led them to answer the items they knew about and to leave blank those they were not familiar with, we suspect that had respondents not been knowledgeable on the topic they would not have answered the question at all due to the close relationship of the items. We have assumed, therefore, that the last cause for item non-response presented earlier prevailed over the others and as such was the driving force behind missing responses for those questions. More specifically, our assumption is that in the absence of a 'zero percent' category respondents would not mark the next best ('less than 10%'). Thus, missing data for those items were assigned to that category, as long as another item of the same question had been responded. This approach was used to reduce the bias upwards and thus to avoid overemphasis on a particular category. However, the number of responses was large enough to not allow the results to statistically differ; the latest average when non-responses were taken into account was not found to differ statistically, on the basis of t-tests, from the earliest average when non-responses were not accounted for.

Non-response is inevitable in any survey and the concern is not only about item non-response but also about unit non-response. As one of the purposes of survey research is to infer about a population based upon a subset of that population, attention has to be drawn as to how well the sample represents the population from which it comes. For a sample to be representative of a population, non-respondents should not differ from respondents. In order to check for how representative was our sample, we compared average R&D expenses in 2000 (data available from the UK *R&D Scoreboard*). The only problem with this procedure is that the third round of data collection was based upon an online questionnaire which did not allow us to match the responses to their respondents. As reported elsewhere in this thesis, legal matters did not allow us to identify the respondent, and therefore they were not categorized in the sample that positively replied to our request.

Table 20 – Average R&D Expenses by Respondent/ Non-Respondent to the Patent Survey

	n	R&D 2000 (£ Million)			
		mean	sd	min	max
Non-respondent	357	32.30	187.85	0.02	2526
Respondent	38	35.13	78.91	0.28	371
R&D Scoreboard	395	32.57	180.20	0.02	2526

Table 20 clearly shows that in the aggregate the average R&D expense in 2000 of the sample (respondents) is slightly higher than the average R&D expense of non-respondents. A comparison between mean scores of the two groups was carried out using a t-test, which according to the literature is the most appropriate statistical procedure when the variable is measured in interval or ratio levels, that is, on a continuous scale (Sheskin 2004). In doing so, we could identify whether that difference and a few others were statistically significant. The t-test relies on a few assumptions[156] amongst which is the equality of the variances of the populations from which the groups come. This particular assumption can be tested by the Bartlett's test (Black 1999). So, an

[156] Continuous scale; random sample; cases independent of one another; normal distribution; equal variances.

analysis of variance was carried out as well before using the t-test to compare respondents and non-respondents.

The results (Appendix 11) indicated that the null hypothesis of equal variance could be rejected (chi^2=32.18 [1 d.f.], p<0.001). In relaxing the equal variances assumption, the t-test showed that the null hypothesis of equal means could not be rejected ($|t|$ = 0.18, p=0.8616). That is, the average R&D expense of respondents does not significantly statistically differ from the average R&D expense of non-respondents. This result lends support to the idea that the sample is representative of the survey population. Other known characteristics were also explored, namely sales ($|t|$=0.97, p=0.3384), profits ($|t|$=0.64, p=0.5270), and R&D expenses per employee ($|t|$=1.10, p=0.2788). They corroborate the initial findings, i.e., that there exists a high degree of likeness between respondents and non-respondents[157]. It is fair to say that while the means are fairly similar for the sample and population, the minimum and maximum values differ. In the absence of further evidence, the sample seems to be representative of the survey population despite the low rate of return achieved and thus the low rate of return should not be matter for major concern. As observed by Fowler (1993), the more alike are respondents and non-respondents, the lower the rate of return can be.

Despite the similarities between respondents and non-respondents, the literature on survey method suggests that early respondents may possess

[157] The assumption of equal variance was relaxed, according to Bartlett's test in Appendix 11.

different characteristics from late ones (Fowler 1993). The prime reason that causes that event is supposed to be the level of interest in the topic of the survey. It is expected that early respondents have stronger interest in the survey than late respondents. As a result, the latter may be less rigorous in filling in the survey instrument, and this may cause a bias. To detect any change in respondents' characteristics over response time we employed the t-test in the same way as when comparing respondents and non-respondents. However, in this case the comparison was between respondents to the first wave of questionnaires and respondents to the second wave[158]. Again, the equal variance assumption was relaxed on the basis of the Bartlett's test (see Appendix 12). The results suggest that late respondents do not seem to differ from early respondents as to the average R&D expenses because the null hypothesis that their mean scores are the same could not be rejected ($|t|=0.39$, $p=0.7003$). Moreover, no statistical difference was observed in terms of sales ($|t|=0.67$, $p=0.5117$) and profits ($|t|=1.08$, $p=0.2888$). The only exception was the R&D per employee ratio ($|t|=2.07$, $p=0.0486$). Overall, it seems that the increased stimuli received by late respondents (in the form of follow-ups) may not have caused any serious bias during the data collection process, which strengthens the external validity of the survey.

[158] Due to identification constraints detailed earlier the third wave of respondents could not be compared.

6.6 VALIDITY & RELIABILITY

The quality of data gathered is in general difficult to measure. It is easier to assess the accuracy of the instrument used to collect the data (Litwin 1995). This assessment is made by analysing the reliability and validity of the survey instrument. Reliability stands for the statistical measure of how reproducible are the data generated by the instrument, whereas validity regards the extent to which the instrument measures what it is intended to measure.

Validity may depend on subjective assessments that collectively improve the quality of the instrument. Thus, both untrained individuals (face validity) and those who have knowledge in the area (content validity) can give their contribution. However, it is also possible to measure how a new instrument performs in comparison to another one considered as the standard for measuring the same variable (concurrent validity). But it depends on how much literature is available on the topic investigated. Another important element is the capacity of the survey instrument to forecast future events, attitudes and so on (predictive validity). Moreover, correlations between i) different ways for obtaining the same information (convergent validity) or ii) similar but distinct concepts (divergent validity) can be checked. In general, correlation analyses are used (Litwin 1995).

Table 21 - Validity Test of the Survey Instrument

Pairs of questions	Spearman	Kendall
Q.B10 *vs.* Q.B15c	0.4240	0.4178
	P=0.0080	P=0.0097
Q.A8 *vs.* Q.C13b	0.7543	0.6354
	P<0.0001	P<0.0001
Q.D4 *vs.* Q.C13a	0.5759	0.4788
	P=0.0001	P=0.0001

In order to cross-check the consistency in the responses to our survey, a few pairs of questions addressing the same issue were formulated in different ways. Due to the discrete ordered nature of the scale the correlations between the questions of each pair were measured by Kendall's and Spearman's rank order correlation coefficients. Table 21 shows the correlations as well as the level of significance of whether we can reject (or not) the null hypothesis that the questions are independent. According to the results, there is no apparent reason why the questionnaire should be deemed invalid, though stronger correlations could improve its validity.

Table 22 - Reliability Test of the Survey Instrument

Question	Cronbach's alpha
A8	0.5955
A10	0.6292
B5	0.5446
B6.1	0.6488
B6.2	0.7090
B12	0.7228
B13	0.7335
B15	0.6008
C11	0.6008
C13	0.8482

Reliability can be assessed by i) measuring the same thing in the same way at more than one point in time (test-retest reliability), ii) changing the order of the response set (alternate form reliability), and/ or iii) measuring internal consistency. The latter can be calculated using a coefficient of reliability known as Cronbach's alpha (Black 1999). That is the most commonly employed measurement and detects the inter-item consistency. Cronbach's alpha coefficient also allows one to identify the extent that a set of items (or variables) can measure a single latent construct. However, when data have a multidimensional structure, Cronbach's alpha is usually low. Levels of 0.70 or more indicate good reliability, though exploratory studies may have lower (Litwin 1995). In fact, as shown in Table 22, the results of the reliability test of our instrument provide an average Cronbach's alpha of 0.66.

The exploratory character of this study may have contributed to both validity and reliability not being very high, though the estimates are not unsatisfactory. Unfortunately previous studies have not reported such measurements.

6.7 Conclusions

This chapter reports the main steps of a new postal survey administered with the purpose of collecting information on the use of patents by manufacturing firms in the UK.

A lot of effort was devoted to designing and administering the survey. Our analyses indicate that, even if not free of errors, the whole survey process has produced an acceptable body of information from which inferences can be drawn. The next chapter builds upon the data collected, furnishing results of basic statistical analyses and contrasting the findings with existing literature.

CHAPTER 7

THE USE OF PATENTS

IN UK MANUFACTURING:

NEW SURVEY EVIDENCE

7.1 INTRODUCTION

This chapter presents the findings of a new survey of the use of patents in UK manufacturing. Despite the tradition in the UK of studying patents there has not been, as far as we know, any attempt to understand how firms build their patent portfolios i.e. there is no extant consistent investigation of firms' decision making re why, when and where they patent. Moreover, there is a similar gap in our knowledge as to firms' policies on patenting. On the basis of a postal survey of manufacturing firms listed in the UK *R&D Scoreboard 2001*, this chapter extends the existing literature by providing evidence on these issues. Due to the exploratory character of this study, no formal hypotheses are tested, rather the study explores the revealed patterns in the data.

The next section presents the results of the survey. The third section places these results in the context of the existing literature. Finally, conclusions are drawn in section four.

7.2 FINDINGS

7.2.1 *SAMPLE PROFILE*

Questionnaire responses indicate that of the sample firms 89% have their head office located in the UK. Of those whose head office is located abroad, only one firm reported to not be responsible for its own patenting activities. That firm, however, has a patent attorney in the UK who responds to the head office. Respondents reported to have an average of 14 years dealing with patent issues, and half of them were occupying mostly intellectual property related jobs at various levels (agent, administrator, director, vice-president). The other half of respondents were split between technical directors (or analogous - e.g., R&D director) and managing directors, 40% for the former and 10% for the latter.

On average 4% of firms' R&D expenses were reported to be allocated to basic research, 37% to applied research 43% to design and/or development, and 16% to technical services. Overall, expenses on applied research and design and/or development do not statistically differ ($|t|=1.14$, $p=0.2573$). Yet, the proportions of their R&D budget allocated to applied research and design and/or development seem to slightly differ across 'industries'. Firms in the discrete industry invest on average 44% of that budget in applied research, while firms in the complex industry invest 29% in similar activity ($|t|=1.96$, $p=0.0580$). Design and/or development account for around 52% of R&D expenses in the complex industry and around 36% in the discrete industry ($|t|=2.09$, $p=0.0436$).

The mean R&D intensity (R&D expenditures divided by sales) of the sample is 48.5%. This figure reflects the incorporation of firms whose R&D outlays are larger than their own sales. If these cases were dropped from the sample the average R&D intensity would fall to 7.2%, which is still much higher than the average R&D intensities of both Japanese firms (3.7%) and US firms (2.3%) surveyed by Cohen et al. (2002). Although total R&D outlays were not found to differ across industries ($|t|=0.24$, $p=0.8129$), the same did not happen to R&D intensity ($|t|=2.28$, $p=0.0288$). The average R&D intensity in the discrete industry (104%) was found to be larger than in the complex industry

(6.2%). Again, reflecting the presence of firms whose R&D expenses are larger than their sales. Dropping those firms from the sample there was no inter-industry difference with respect to R&D intensity ($|t|=0.73$, $p=0.4701$). That R&D effort has been able to create a range of inventions which are portrayed in part by firms' average portfolio of 650 patents, 110 of which are registered in the UK. Interesting is that despite inter-industry differences in R&D intensity, no significant (statistically) difference was found between the size of the portfolio of discrete and complex industries. Neither at global level ($|t|=0.55$, $p=0.5847$) nor at UK level ($|t|=0.72$, $p=0.4815$).

7.2.2 *PATENTS AND APPROPRIATION*

Manufacturing industry has a long tradition of using patents to appropriate the returns from innovation. To measure the contribution of patents relative to other means of appropriation respondents were asked to report the proportion of their innovations (products or processes) for which patents and other methods of appropriation have been key in increasing their returns (Q.A8 & Q.A10). Six response categories were given: 1) less than 10%, 2) from 10% to 30%, 3) from 31% to 50%, 4) from 51% to 70%, 5) from 71% to 90%, and 6) more than 90%. The results were calculated by using the mid-points of each category, and are presented in Table 23. The findings suggest that patents ($|t|=2.25$, $p=0.0273$) and being first mover ($|t|=2.62$, $p=0.0105$) are the only methods of appropriation that are significantly different in their contribution between product and process innovations. Both seem to be more effective when the innovation is a product rather than a process.

Table 23 - Methods Considered Key Elements in Increasing Returns (% of Innovations)

Method of Appropriation	n	Products		Processes	
		mean	s.e.	mean	s.e.
Patents**	46	48.60	5.64	30.86	5.51
First mover**	46	41.98	4.63	25.00	4.52
Complem. Sales/ service	46	35.81	4.63	23.86	4.68
Control of mfg. facilities/ capabilities	46	33.72	4.82	41.00	6.09
Secrecy	46	33.14	5.06	39.43	5.94
Complem. technological components	46	27.09	4.36	21.43	3.70
Switching costs	46	14.07	2.98	17.00	3.98

** Differences in means (product *vs.* process) significant at 0.05 level.

The results also indicate that although patents are perceived to be one of the most important means by which to increase the returns from product innovations, this is not unambiguous. Their contribution is not statistically different either from first-mover advantages ($|t|=0.87$, $p=0.3915$) or from the provision of complementary sales or services ($|t|=1.61$, $p=0.1153$). Patents seem to be more important than secrecy ($|t|=2.19$, $p=0.0338$) in increasing the returns from product innovations. However, this does not apply when the innovation is a process innovation when no significant difference was identified between patents and secrecy ($|t|=1.07$, $p=0.2935$), which is somewhat surprising in the light of previous studies (e.g., Cohen et al. 2000, Levin et al. 1987).

The importance of patents is further examined by another question (Q.C13b), which asks respondents to rate the extent to which they agree or disagree with the following statement: "patents are decisive in increasing the returns from our innovative effort". The scale is from 1 (strongly disagree) to 6 (strongly agree). The median score obtained was 4. This lends support to the results in Table 23 where patents are regarded key to increasing the returns for about half of all product innovations, though a lower proportion of processes innovations (about 30%). The measurement of agreement does not distinguish between the types of innovation (products *vs.* processes). Spearman's rank order correlation coefficient[159] indicates that responses to both questions (proportion and degree of agreement) are positively correlated, but more strongly correlated with product (r_s=0.7543, $p<0.0001$) than with process (r_s=0.5493, p=0.0011) innovation. As expected, there is a bias towards product innovations since they are the most probable output of firms' innovative effort.

In addition to asking what is the proportion of innovations that have higher returns because of patents, respondents were asked to report what share of those innovations correspond to their most valuable innovations (Q.A9, Q.A11). The means for product and process innovations were 39% and 30%, respectively[160]. Respondents also reported the extent of their agreement with the following statement (Q.C13g): "Our most valuable innovations would not bring high returns if they were not patented". Again, their degree of agreement is more strongly correlated (Spearman's rank order) with the proportion of product innovations (r_s=0.6510, $p<0.0001$) that have their returns increased by patents than with the proportion of process innovations (r_s=0.4428, p=0.0111) whose returns were enhanced by that type of intellectual property rights.

[159] This is a measure of correlation between two variables that are rank-ordered (Sheskin 2004). Note that in one of the questions a percentage scale is employed but it is, in fact, in a rank-order format, where, for example, the scale 'less than 10%' equals 1, from 10% to 30% equals 2, and so on.

[160] They are not statistically different ($|t|$=1.04, p=0.3052).

The median score to the statement that patents are decisive in increasing the returns of innovation (Q.C13b) was not found to differ between complex and discrete industries (chi^2 [1d.f.]=2.273, p=0.1316)[161]. Nor was the average proportion of product ($|t|=1.46$, p=0.1533) and process ($|t|=1.45$, p=0.1557) innovations for which patents play a key role in increasing their returns found to differ by industry. However there does seem to be a difference between complex (median=3) and discrete (median=5) industries with respect to the extent that their most valuable innovations (Q.C13g) depend on patents to bring higher returns (chi^2 [1d.f.]=4.880, p=0.0272)[162]. Although the discrete industry's most valuable innovations seem to be more dependent on patents (Q.C13g), it does not mean that their most valuable innovations are patented more often than the most valuable innovations in the complex industry (Q.A9, Q.A11)[163].

Firms in the complex industry were expected to be more likely to use patents to give freedom of operation than firms in the discrete industry. In examining that mutual dependence, firms were asked to report (Q.D14) the importance (over the last three years) of securing property rights over inventions linked to other firms' inventions. Somewhat surprisingly, the findings indicate that firms in complex and discrete industries do not differ in their use of patents to provide access to other firms' inventions (chi^2 [1d.f.]=0.581, p=0.4460). Furthermore, the findings revealed that if firms need to

[161] As the response scale is in ordinal format, Kruskal-Wallis one-way analysis of variance by ranks was used to test whether the medians of the two groups (complex and discrete) are equal (Sheskin 2004).

[162] Based on the Kruskal-Wallis one-way analysis of variance by ranks.

[163] Product innovations: $|t|=1.48$, p=0.1547; process innovations: $|t|=0.70$, p=0.4944.

have access to inventions patented by other firms, the fact that they do have their own patent portfolio is more useful for firms in the discrete industry than in the complex one[164]. We suspect it is necessary to undertake further research in order to clarify this point.

7.2.3 *MOTIVATIONS TO PATENT*

The extent that firms pursue patents was explored by a series of questions. They were asked, for example, whether (or not) they had any annual numerical target for patent filings in 2002 (Q.B1). About 17% answered yes, with an average target of 49 patent applications[165] per year. They also revealed what best could describe their attitudes with respect to their inventions (Q.B4). Four alternatives were given: i) they do not patent anything, ii) they patent what may be used or market by their company, iii) they patent what may be used or marketed by their company or by their main competitors, and iv) they patent nearly everything. The distribution is shown in Table 24.

Table 24 – Patent Policies by Type of Innovation

Patent Policy	% of Respondents	
	products	processes
Do not patent anything	6.52	17.07
Patent what may be used or marketed by own company	26.09	34.15
Patent what may be used or marketed by own company or by main competitors	47.83	36.59
Patent nearly everything	19.57	12.20

As expected, only 3 out of 46 responded that they do not patent and these said that this was so for both types of inventions. Interestingly those who

[164] Median score 3 against median score 2 in a 1 to 6 scale of agreement.

report that they patent nearly everything are mainly small or medium-sized firms (Appendix 13), which would be expected to suffer more from financial constraints. One justification for their attitude is that they are the most R&D intensive firms (Appendix 14).

Figure 3 - Patent Policy Towards Product Inventions by Industry

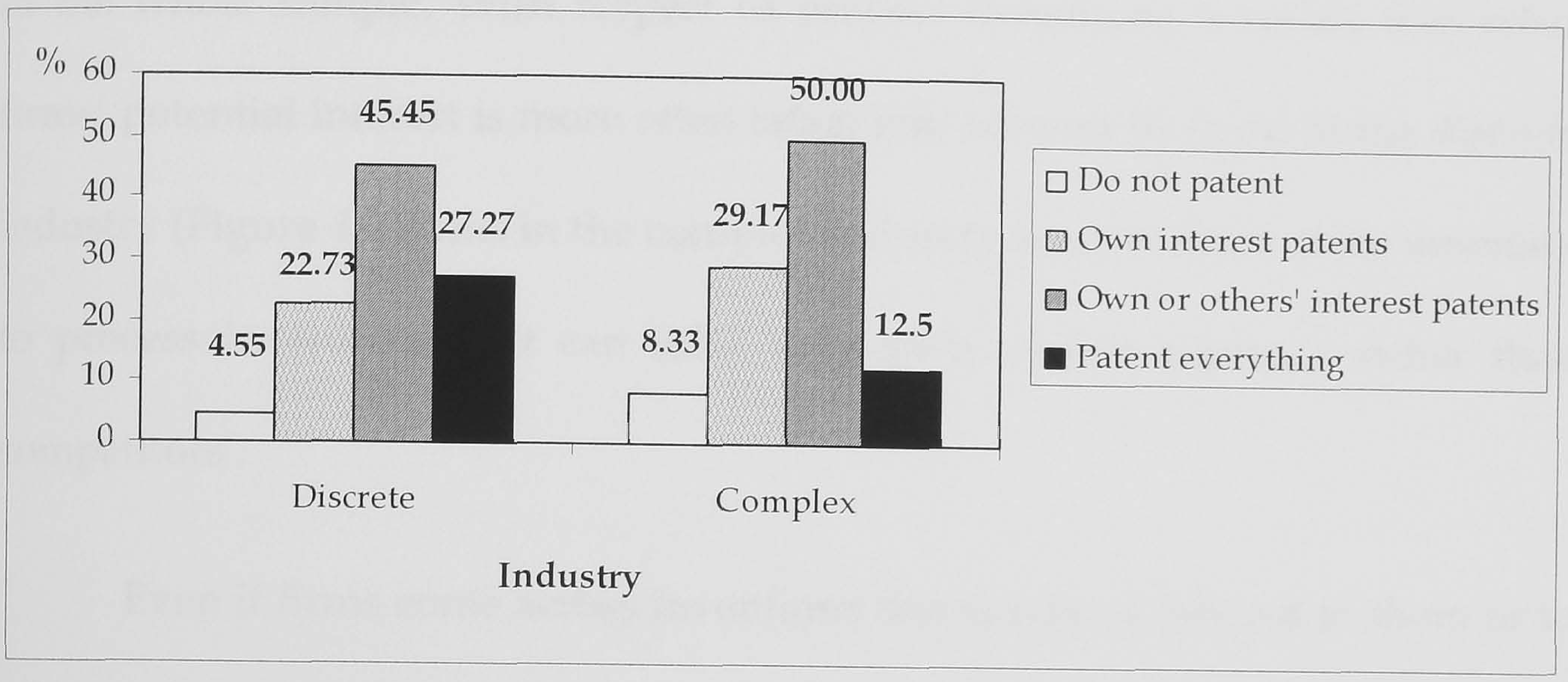
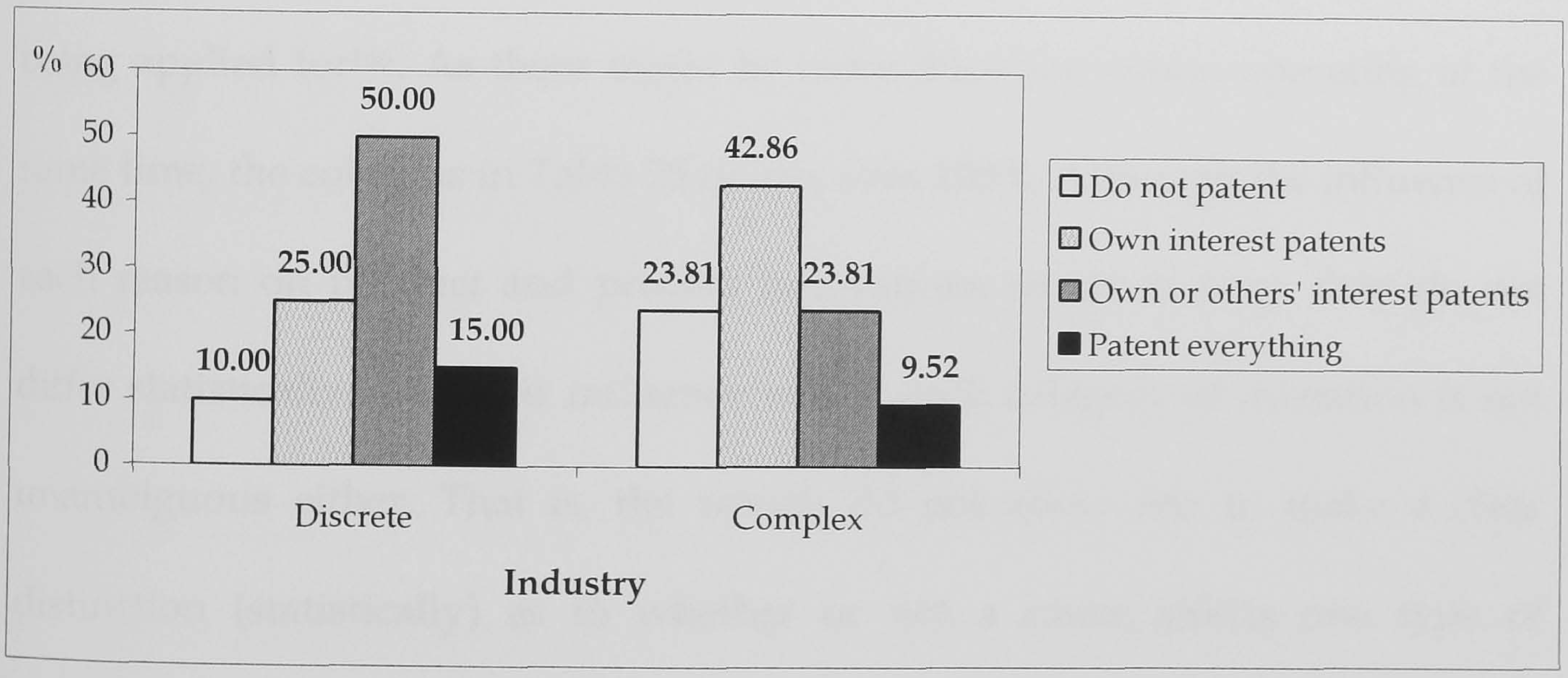


Figure 4 - Patent Policy Towards Process Inventions by Industry



[165] Range from 3 to 120.

The distribution of firms' policies was compared by industry and type of invention. Overall, firms' policies do not seem to differ that much between complex and discrete industries. The policy of pursuing patent protection for nearly every product invention seems to be more often pursued by firms in the discrete industry (Figure 3), more specifically by the most R&D intensive firms in the whole sample. With respect to process inventions it seems that other firms' potential interest is more often taken into account by firms in the discrete industry (Figure 4). Firms in the complex industry seem to draw more attention to process inventions that can fulfil their own market interests rather than competitors'.

Even if firms come across inventions that can be of interest to them or to other firms they may not pursue patent protection. To understand why firms do not patent they were asked (Q.B6) to rate the proportion of their inventions (product and process) for which a particular reason contributed to a patent not being applied for[166]. As there might be more than one reason operating at the same time, the columns in Table 25 do not sum 100%. Although the influence of each reason on product and process innovations seems to vary, they do not differ statistically, and their influence within each category of invention is not unambiguous either. That is, the results do not allow one to make a clear distinction (statistically) as to whether or not a cause affects one type of

[166] Scale used: 1) less than 10%, 2) from 10% to 30%, 3) from 31% to 50%, 4) from 51% to 70%, 5) from 71% to 90%, and 6) more than 90%.

invention more than another. Nor do they allow to decide which is the main cause hampering the patenting of each type of innovation.

Table 25 - Motivation for Not Filing Patent Applications

Reason	Product (%)		Process (%)	
	mean	s.e.	mean	s.e.
Ease patents are legally circumvented	33.56	4.57	33.92	5.25
Costs of application	31.44	5.11	29.87	5.34
Difficulty in detecting infringement	30.22	4.87	41.13	6.01
Technological pace	26.67	4.32	25.38	4.90
Difficulty in demonstrating patentability criteria	24.67	3.75	27.31	4.86
Uncertainty as to the validity of the patent	21.56	3.70	17.56	2.88
Amount of information disclosed	20.33	3.92	28.85	4.97
Difficulty for other firms to copy the invention	19.69	3.21	26.15	4.73
Costs of disputes	16.44	3.35	16.79	3.00
Ease of being induced to cross-licensing	9.78	1.38	9.10	1.35

Although the highest average proportion of product inventions that were not patented seems to be a consequence of the ease with which someone else can invent around a patent, it does not differ (statistically) from the average proportion of product inventions whose patenting was hampered by one of the following: i) the costs of the application process, ii) the difficulty in detecting infringement, iii) the rate of technological progress, and iv) the difficulty in demonstrating patent criteria[167]. The average proportion of product inventions that were not patented due to inventing around risks is, however, different from the average proportion of the same type of inventions that were not patented caused by i) the uncertainty as to the validity of the patent, ii) the amount of information disclosed, iii) the difficulty for other firms to copy the

[167] $|t|=0.31$, $p=0.7590$; $|t|=0.50$, $p=0.6190$; $|t|=1.09$, $p=0.2766$; and $|t|=1.5036$, $p=0.1364$, respectively.

invention, iv) the costs of defending a patent in court, and v) the ease of being induced to cross-licensing[168].

Nevertheless, the results from Table 25 are in line with the findings presented in Table 23, where secrecy was ranked as one of the most important mechanisms for increasing returns from process innovations. Table 25 lends further support to those results by indicating that perhaps what is mainly behind firms' decisions not to patent process innovations is the difficulty of detecting infringement, although we cannot formally test this. Clearly, the widespread use of secrecy makes things difficult if a firm is willing to detect infringement against its patented process inventions. The results, however, do not elucidate whether this is really the driving force that hampers the patenting of process inventions. The average share of process inventions that was not patented on account of the difficulty in detecting infringement is not statistically different from the average share resulting from: i) the ease with which patents can be legally circumvented, ii) the costs of prosecuting a patent application, iii) the amount of information disclosed, iv) the difficulty in demonstrating patentability criteria, and v) the difficulty for other firms in copying the invention[169]. The impact of the difficulty in detecting infringement was found to differ from i) the pace of technological change, ii) the uncertainty

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[168] $|t|=2.04$, $p=0.0446$; $|t|=2.20$, $p=0.0308$; $|t|=2.48$, $p=0.0152$; $|t|=3.02$, $p=0.0034$; $|t|=4.98$, $p<0.0001$, respectively.

[169] $|t|=0.90$, $p=0.3692$; $|t|=1.40$, $p=0.1656$; $|t|=1.57$, $p=0.1196$; $|t|=1.79$, $p=0.0778$; and $|t|=1.96$, $p=0.0541$, respectively.

as to the validity of the patent, iii) the high legal costs of defending a patent in court, and iv) the high probability of being induced to a cross-licensing.

With a few exceptions, for most reasons listed in Table 25 no difference was found between complex and discrete industries. The ease of inventing around patents is one of the few that seems to affect more seriously the complex industry than the discrete one for both product ($|t|=3.62$, $p=0.0008$) and process ($|t|=2.79$, $p=0.0082$) inventions. Along the same lines, uncertainty as to the validity of the patent is statistically different between complex and discrete industries for both product ($|t|=3.30$, $p=0.0025$) and process ($|t|=2.27$, $p=0.0302$) inventions, but the effects on the complex industry were found to be more pronounced. The last difference observed between both industries, but now only at product level, was the average share of inventions less likely to be patented because of the amount of information that would be disclosed; a concern stressed more by firms in the discrete industry.

Firms were asked to identify the proportion of their inventions that was a result of deliberately circumventing someone else's patents (Q.B7, Q.B8). Although firms in the complex industry seem to be more concerned about competitors circumventing their own patents, they do not seem to use this procedure more frequently than firms in the discrete industry. Deliberately inventing around other firms' patents was not detected to be a common practice in either industry[170], and no significant difference between industries was

[170] Around 10% of inventions are produced in that way.

observed for product (|t|=0.02, p=0.9872) or process (|t|=1.26, p=0.2167) inventions. These findings are perhaps a result of what firms decide not to patent, that is, inventions easy to circumvent. As they are more likely to apply for patents that are relatively difficult to engineer around, it might be relatively costly to pursue that avenue.

Induced cross-licensing was found to exert only a marginal influence on the decision not to apply for a patent. Results from the previous sub-section point out that there exists no difference between the UK complex and discrete industries with respect to the use of patents to assure freedom of operation by securing patent rights essential to other firms. Our previous finding thus has further support. In addition, no inter-industry difference was detected. That is, the percentages of product (|t|=0.50, p=0.6206) and process (|t|=0.55, p=0.5858) inventions that are not patented because of the risks of an induced deal were not found to differ between discrete and complex industries. A specific question (Q.B10) about the percentage of firms' patent portfolios corresponding to patents consciously designed to surround someone else's patents in order to lead to a deal gives further support to this evidence. Neither firms in the complex industry nor firms in the discrete industry seem to devote much attention to that practice. The average share of their patent portfolio built for that purpose is about 8% for both industries (|t|=0.07, p=0.9446), on the basis of the response scale described above.

So, it seems indeed that cross-licensing is not commonly used by firms in the UK, at least for the purposes of avoiding delay. Thus, firms may be more inclined to defend their legal rights and go to court, if necessary. As a result, patent disputes would be expected to be more frequently observed, especially in the complex industry. However, if this was the real cause, perhaps complex firms would be more concerned than discrete firms about the costs of defending their patents in court, and this was not found. Nevertheless, the similarity in responses to this item (legal costs) may be a result of sunk costs that are common to both industries, and not of foreseeable costs that would be likely to be higher due to the risks of legal disputes.

Firms were questioned about the proportion of the patent infringements against them that was ignored, resolved by simple notification, resolved by out of court settlement, or resolved by court litigation (Q.B9). Overall, most of patent infringements were said to be resolved by simple notification[171], though not statistically different from other options. Moreover, no difference was found between complex and discrete industries[172]. Firms were also asked up to what age of a patent they would be prone to defend themselves against infringements (Q.B11). On average, they are keen on defending their patents up to 60% of their length[173]. Complex firms, on average, reported to defend patents up to 57% of their life while discrete firms said that on average they would defend patents up to 69% of their life.

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[171] Mean 25.66%, s.e.=4.45.

[172] Perhaps an item asking about the proportion of infringements not resolved could shed light on this, but this was not addressed in the questionnaire.

[173] Mean 62.56%, s.e.=4.78.

Table 26 - Reasons Why Firms Apply for Patents

Motivation	(%) Applications	
	mean	s.e.
To preclude others from freely copying inventions	68.98	4.32
To avoid others from patenting a similar invention	55.57	5.17
To prevent others from patenting variations of the invention	53.98	5.35
To increase competitors' costs to invent around patents	36.93	5.16
To enhance the reputation of firm	34.89	5.07
To obtain revenue through licensing-out	28.18	4.87
To get a better bargaining position in standard-setting	21.82	4.30
To have access to a foreign market	20.45	4.22
To get a bargaining position to have access to another patent/ technology	19.89	3.44
To avoid infringement trials	17.95	4.07
To facilitate R&D co-operation with other inventors	16.36	3.30
To incentivise researchers	11.82	2.88
To show the productivity of R&D	11.59	2.31
To signal interest to others	11.36	2.24
To mislead competitors as to the true technological path	7.16	0.93

Another question (Q.B12) addressed the motivation behind firms' pursuit of patents. Strictly speaking, they were asked the proportion of their patent applications that were filed according to a number of factors, as shown in Table 26. Not surprisingly, firms reported that the major reason why they file patents is to pre-empt others from deliberately copying (and commercializing) their inventions. Although accounting for a lesser proportion ($|t|=2.55$, $p=0.0145$) firms also file patent applications to avoid someone else doing so, which could preclude them from accruing higher returns from the innovation or even not being able to reap any benefit at all. Accounting for approximately the same proportion ($|t|=0.35$, $p=0.7275$) as the previous reason, the objective of preventing others from patenting variations of the invention was also perceived as an important element that has led firms to apply for patents. This protective behaviour is also reflected in the fact that firms seek patent protection in order to increase competitors' costs of inventing around their patents, though the extent to which this reason impacts on patenting decisions is lower than the previous two[174].

It was detected from the findings reported in Table 25 that on a few occasions the reasons for not filing patents affect the complex and the discrete industries in different ways. Firms in the complex industry reported to be more concerned than firms in the discrete industry with inventing around and the validity of their patents. Comparing the industries on the basis of the results of Table 26, the major difference between them concerns the importance assigned to the costs of inventing around patents ($|t|=2.06$, $p=0.0455$). The complex industry reported that a higher proportion of its patent applications is devoted to increasing competitors' costs. Another (statistical) difference between both industries is the proportion of their filings used to access foreign markets, though the evidence is not particularly strong ($|t|=2.01$, $p=0.0505$). The discrete industry was detected to have a higher proportion of its patents (about 29%) for that purpose than the complex industry (about 13%).

For the remainder of the motivations addressed in Table 26 there was no statistical difference between the two industries. In both industries, for example, only a marginal share of the inventions seems to be patented in order to dissuade competitors, and about the same proportion ($|t|=1.77$, $p=0.0841$) of inventions is patented to show any signal to the market. Further, neither the percentage of inventions that are patented in order to show the productivity of

[174] $|t|=3.43$, $p=0.0013$; $|t|=2.83$, $p=0.0071$, respectively.

R&D nor the share used to incentivise researchers differ statistically from the proportion of filings motivated by misleading competitors[175].

Table 25 showed that a relative large percentage of inventions (20% of product inventions and 29% of process inventions) is not translated into patent applications because of the knowledge they disclose. One possible explanation for that (especially regarding process inventions) lies in Table 26, which reports that patent holders do not seem to bluff on their technology bets. Thus, the signal sent to the market by patentees is that those inventions for which a patent is applied for are potential sources of revenues, and hence may incite other firms to pursue the same technological path, which in general is built upon the knowledge disclosed by previous patents.

In another question (Q.D5) respondents were asked to rank[176] in order of importance their reasons for using patent information. The results are presented in Table 27. Despite firms' concern about the information disclosed it seems that technical knowledge is less relevant than expected. The responses seem to draw more attention to potential overlaps of knowledge than to the absorption of knowledge itself. But this could be because the information was addressed in a general way. Another question (Q.D4) asked respondents to rate[177] how useful is the information disclosed by other inventors' patents in guiding their R&D activities. An average of 3.2 reflects the medium-low importance of patent

[175] $|t|=1.77$, $p=0.0838$; $|t|=1.57$, $p=0.1227$, respectively.

[176] From 1 (most important) to 6 (least important).

[177] From 1 (not at all useful) to 6 (very useful).

information. The relationship between the two questions (Q.D4 and Q.D5) was examined by the Spearman rank order correlation[178]. As the scales of both questions work in opposite directions, a negative sign means a positive correlation. This reflects the type of information that is more likely to be of interested to R&D activities.

Table 27 – Reasons for Using Patent Information

Reason	mean rank[a]	s.e.	median
To check if an invention was already patented	2.17	0.23	2
To check on potential patent infringement	2.88	0.24	2
To keep track of competitors	2.91	0.24	3
To find information relating to a specific technological problem	4.09	0.21	4
To keep abreast of technological changes	4.21	0.21	4
To obtain market information	4.74	0.24	5

[a] Where 1 is most important and 6 least important.

Table 27 and Table 28 both show that patents are mainly used to detect whether there is any risk of infringing another patent. A clear distinction between the tables is the role played by patent information at different levels (i.e., managerial, technical). Although patents are deemed more useful to map the competitive terrain than to provide technical knowledge, for R&D purposes that type of information does not seem to be so important (compared to other options provided). One can observe (Table 28) that the relationship between knowledge spillovers (i.e., to find information relating to a specific technological problem) and the importance of patent information to R&D activities follow the same direction (i.e., negative sign) whilst the relationship

[178] Both scales are in ordered format but in opposite direction.

with market-related information (i.e., to keep track of competitors; to obtain market information) goes in the opposite way (i.e., positive sign).

Table 28 - Relevance of Information to R&D Activities

Type of information	Spearman's rho
To check if an invention was already patented	-0.1425
To check on potential patent infringement	-0.0795
To find information relating to a specific technological problem	-0.0480
To keep abreast of technological changes	0.0033
To keep track of competitors	0.0377
To obtain market information	0.2600

No difference[179] was found between complex and discrete industries as to the importance of each type of information obtained from patents, though information disclosure as a whole was found, based upon the results of Table 25, to exert more influence on the discrete industry than in the complex industry. As firms in the discrete industry reported that a larger share of their patent applications is filed to gain access to foreign markets, their exposure to other firms is naturally higher, and hence may lead them to perceive higher risks associated with information disclosure. Or perhaps this is a consequence of the way their patent portfolio is structured.

7.2.4 *Patent Portfolios*

While patent policies might condition the extent to which firms can appropriate profits from their innovative effort, the degree of appropriability conferred by patents may depend upon the structure of firms' portfolios. Our survey provides information on the way patent portfolios are built in UK

[179] Based on the Kruskal-Wallis one-way analysis of variance by ranks.

manufacturing by addressing firms' decisions on i) where, ii) what, and iii) when to patent.

Firms were asked (Q.C10) to report in descending order in which countries (five at most) they file the largest share of their patent applications. Five firms, that is 12.5% of respondents to this question (n=40), reported they apply only to the UK Patent Office. The majority of firms said that they file patent applications abroad. A few firms reported either 'EP' or 'EPO' to indicate their interest in the member countries of the European Patent Office, amongst them the UK. Whilst some of the respondents that answered in that way made a distinction between the UK and Europe, others did not. The same applies to other European countries, France and Germany in particular.

Table 29 - Destiny of Most Patent Applications

Country	% of Total	Mode Rank	Industry	
			% Complex	% Discrete
UK	20.00	1	56.25	43.75
US	20.63	1	51.52	48.48
France	12.50	3	50.00	50.00
Germany	11.88	4	57.89	42.11
Japan	12.50	3	45.00	55.00
Italy	0.63	4	0.00	100.00
EPO	8.75	2	42.86	57.14
China	4.38	5	71.43	28.57
Australia	3.75	5	16.67	83.33
Canada	5.00	5	37.50	62.50

The UK and the US were the countries most often cited as where patent applications are filed (Table 29); each accounting for around 20%. Despite the US being mentioned slightly more often than the UK, the latter was more frequently cited as the country which receives most of the patent applications; about 60% said that the UK Patent Office is where they file most of their patent applications. This percentage could be higher if firms had reported only countries as opposed to regions. The same rationale applies to a comparison between Germany and Japan. Although the latter was ranked more often as the third country to receive patent applications, Germany could account for a larger share if respondents had explicitly pointed out the country as opposed to Europe (mentioned by 8.75% of respondents). The distribution of firms in the discrete or the complex industry is about the same for the most cited countries (i.e., UK, US, France, Germany, and Japan). But the same cannot be asserted with respect to other countries.

To identify what is behind the choice as to the countries where patents are applied for, our survey asked (Q.C11) the proportion of filings abroad that was motivated by a series of factors, as shown in Table 30. The findings suggest that the chief reason leading firms to apply for patents abroad is their current or future presence in the market. A smaller[180] percentage of patent applications is motivated by the size of the market, although it might be that firms either are already trading or envisage running a business there because of the size of the market. Lower costs associated with the patenting process (e.g., translations costs) were ranked the least important reason to choose a country to file a patent application ($|t|=2.28$, $p=0.0284$).

[180] $|t|=3.79$, $p=0.0005$.

Table 30 - Factors Influencing Patent Filings Abroad

Motivation	mean	s.e.
Current or foreseeable participation	74.46	4.50
Size	52.16	6.07
Presence of competitors	50.54	5.58
Enforcement climate	32.97	5.31
World-class technical/scientific competence	21.49	4.44
Territorial proximity	19.73	3.85
Lower costs	10.68	2.12

Differences between complex and discrete industries were found for the enforcement climate ($|t|=2.34$, $p=0.0253$), which seems to be more valuable to firms in the discrete industry. Weak evidence was found to support the hypothesis that current or foreseeable participation in the market ($|t|=1.93$, $p=0.0618$) and/ or the size of it ($|t|=1.80$, $p=0.0804$) influence differently discrete and complex firms. No other indication of differences between the two industries was found.

We saw in Table 26 that firms apply for patents mainly with the purpose of pre-empting competition. Respondents said they are compelled to apply for patents either to bar competitors from freely commercializing their innovations or to make things as difficult as possible for rivals to come up with a competing alternative. They were asked to report (Q.C5) the scope of most of their patents as compared to the average in their industry. They were given five alternatives: substantially broader, slightly broader, no difference, slightly narrower, and substantially narrower. In addition, we asked (Q.C6) the scope that best describes their most valuable patents (Table 31).

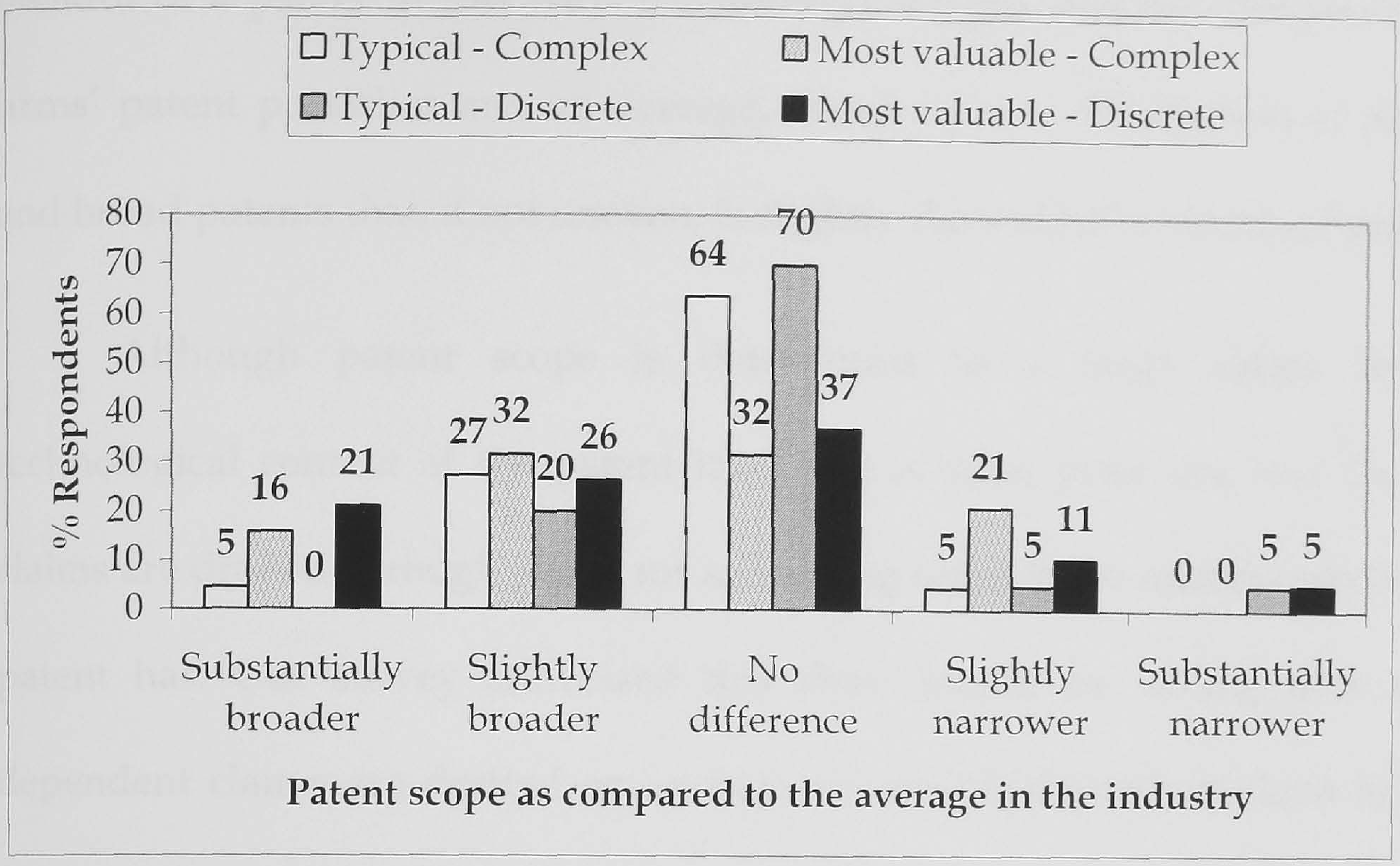
Table 31 - Scope of Patents as Compared to the Average in the Industry

Scope	Percentage of respondents choosing category of scope	
	Majority of patents	Most valuable patents
Substantially broader	2	18
Slightly broader	24	29
No difference	67	34
Slightly narrower	5	16
Substantially narrower	2	3

Firms reported mostly that both the majority of their patents and the most valuable ones have scope equal to the average in the industry. But it is clear that the distribution changes when the focus is on the most valuable ones. Moreover, the percentage distribution of broad and narrow scope is biased towards broad scope, which suggests that firms are more likely to pursue broader patents. However, it does not mean that patents with narrow scope are worthless. On the contrary, Table 31 suggests that narrow patents sometimes can be quite valuable; otherwise, there would be no increase in the percentage of respondents saying that their most valuable patents present scope narrower than the average in the industry.

Figure 5 shows how the scope changes by industry when comparing an average patent to the most valuable one. Generally speaking, it seems that patents with narrow scope are more likely to be valuable in the complex industry than in the discrete industry. In turn, firms in the discrete industry seem to put more value on patents with scope broader than the average.

Figure 5 – Contrasting Patent Scope Between Typical and Most Valuable Patents by Industry



That broad patents are, in general, more valuable than narrow ones was partly corroborated by another question (Q.13j), where respondents rated[181] the extent that they agree (or disagree) with the following statement: "our patents with broad scope are more valuable than our patents with narrow scope". The median score was 4, and the mean score 3.7, which shows only a slight agreement amongst respondents. Further, our survey asked (Q.B15) the proportion of the patent portfolio that is characterized by patents with broad and narrow scope[182]. Respondents answered that they perceive their patent portfolio to comprise mainly patents with broad scope (43%). However, the proportion of narrow patents (34%) does not statistically differ from broad

[181] Scale from 1 (strongly disagree) to 6 (strongly agree).

[182] The scale was 1) less than 10%, 2) from 10% to 30%, 3) from 31% to 50%, 4) from 51% to 70%, 5) from 71% to 90%, and 6) more than 90%. Their mid-points were used to compute the average.

patents ($|t|=1.45$, $p=0.1498$)[183]. Although it might be vague to measure the breadth of a patent in this way, the findings suggest that the composition of firms' patent portfolios are, on average, based upon a distribution of narrow and broad patents that, if not uneven, is slightly skewed towards broad patents.

Although patent scope is determined to a large extent by the technological content of the patent itself, the existing prior art, and the way claims are drafted, a rough proxy for measuring scope is the number of claims a patent has. Our survey addressed this characteristic by asking how many dependent claims are drafted on average for each independent claim of their typical patents (Q.C7). The rationale underlying this question is that the broader an independent claim is drafted, the more it will need dependent claims to support and protect it from being challenged.

Table 32 – Number of Dependent Claims per Independent Claim

Number of dep. claims per independent claim	% Respondents	
	Typical	Most Valuable
Less than 5	11	14
From 5 to 10	46	34
From 11 to 15	31	31
From 16 to 20	6	14
From 21 to 25	3	6
More than 25	3	0

Table 32 lends support to previous findings that the most valuable patents are not necessarily the broadest ones. While, on balance, the result does seem to favour broader patents, the distribution of the most valuable patents

[183] The average proportion of narrow and broad patents do not differ by industry either; $|t|=0.85$,

seems to move from the middle to both extremes (i.e., broad and narrow). To measure the degree of association between the two measures (Q.C5 and Q.C7) we employed Cramer's phi, as suggested by Sheskin (2004), for the scale of scope (Q.C5) and the scale of the number of dependent claims (Q.C7) are more nominal in nature than ordinal. There seems to exist a degree of association between the two variables that, even if not strong (V=0.4055)[184], indicates that a high number of dependent claims may, in fact, be a result of a broad independent claim, and hence a broad patent scope.

In addition to the scope, we asked about the composition of firms' patent portfolios, that is, the percentage of the portfolio that fits into one or more of the categories that we listed (see Table 33). As shown in the last subsection, firms' policies are mainly oriented towards defending themselves against imitators whereas the effort expended to induce other firms to cross-licensing is relatively small. The way patent portfolios are designed may reinforce this approach. Table 33 shows innovators' concern as to precluding others from commercializing their inventions. Their effort to induce others to deal on the basis of overlapping patents seems smaller than the other possibilities. In fact, the average proportion of patents that are developed by surrounding someone else's patents statistically differs from the other categories[185].

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p=0.4017, and $|t|=0.94$, p=0.3535, respectively.

[184] Note, however, that one variable is based upon a relative measure and the other is computed on 'absolute' terms.

[185] Differences between average share of own patents surrounding third parties' patents and average share of other types of design provided the following statistics from the bottom to the top of Table 33: $|t|=2.12$, p=0.0370; $|t|=2.01$, p=0.0481; $|t|=2.64$, p=0.0100; and $|t|=3.49$, p=0.0008.

Table 33 - Patent Portfolio Designs

Design	mean	s.e.
Patents that surround their own patent	22.13	3.29
Patents covering an array of technical solutions	19.13	3.29
Patents with prohibitive invent-around costs	16.13	2.88
Unordered patents	15.75	2.50
Patents that surround patents held by other inventors	9.75	1.33

We have found no difference in the structure of patent portfolios across patent policies presented in Table 24[186]. Nor have we found any difference between complex and discrete industries as to the composition of their patent portfolios. Although earlier findings have shown that firms in the complex industry are keener on pursuing patents with insurmountable invent around costs than are firms in the discrete industry, the latest results suggest that they do not seem to achieve that purpose more often than firms in the discrete industry do.

For reasons explained elsewhere in this thesis, a patent may not be granted because the application does not fulfil the patentability requirements. So, the patent portfolio is not fully within the remit of the firm. One obvious obstacle is what other inventors do (i.e., either applying for or publishing somewhere) that can invalidate the application. If, for example, a firm applies for a patent after another firm has applied, and they encompass the same, or nearly the same, invention, either the later applicant will not hold a patent or he will hold a very narrow patent. In either case the later applicant would be in a more fragile position than he would be if he had applied first. Timing is

[186] Analysis of variance (Sheskin 2004) was used to check for statistical differences across patent policies in the mean percentage of portfolio characterized by a particular type of design.

therefore an important element of the patenting process because other firms' behaviour may jeopardise the potential returns of an innovation.

In order to identify when, along the time profile of innovation process, the first patent application is filed respondents were asked (Q.D8), firstly, how long it takes approximately for the main output of their R&D activities (i.e., product or process inventions) to be generated and be ready for commercialization. Then, they were asked (Q.D10) to report how far from market introduction is a corresponding patent application filed[187]. On average, an innovation was said to take 3.3 years (s.e.=0.46) to be developed and ready to be traded. And a patent was said to be applied for about 2.1 years (s.e.=0.39) before the invention is ready to be in the marketplace. This means that, on average, a patent is applied for after one third of the innovation process has run[188].

Firms in the complex industry were found to develop their inventions quicker than firms in the discrete industry. While in the former it takes about 2.1 years, in the latter the innovation development time is around 4.6 years[189].

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[187] A filter question (Q.D9) was employed here. It asked whether the patent application was filed before or after the launch of the invention. If a patent application is filed after the introduction of the invention, it is very unlikely that the application would fulfil the patentability criteria (e.g., novelty). Thus, a patent would not be granted. And even if it is granted, it will not be valid in court if challenged by someone else. That is, only persons not aware of the topic or not taking the survey seriously would answer 'after market introduction'. This follows Granstrand (1999) recommendation to test the validity of the responses. One questionnaire was discarded for answering 'after'. This is such a serious issue that on more than one occasion respondents highlighted the impossibility of filing patent applications afterwards.

[188] Those values were also calculated without pharmaceutical firms in the sample. Although the average length of the innovation process decreased, the results regarding patent application were about the same. More specifically, it was found that, on average, a patent is applied for after an invention has gone through 35% of the innovation process.

[189] They differ statistically ($|t|$=2.12, p=0.0421).

However, patent applications were detected to be filed more or less at the same time (proportionately). More specifically, they were reported to be filed after the corresponding invention has gone through 33% (complex) or 35% (discrete) of the innovation process.

As firms reported that to a certain degree they seek patents that surround their own patents, it would be useful to know when those later patents appear. Surrounding patents can be a result of subsequent applications that are filed before or after an invention is launched on the market or is ready to be used by the innovator (i.e., process inventions). Filings that incorporate improvements on the initial conceptual idea and that are applied for before the inventions is introduced/ used are defined as follow-ups. Our survey identified those who use follow-ups by asking them to answer a few questions on the topic. They were instructed to jump to the next section of the survey instrument if they did not make use of follow-ups. In that case, it is assumed that if they seek to surround their own patents with other patents, they do so by filing applications after the invention has already been introduced (or is ready to be used). Approximately half of the respondents answered the 'follow-ups questions', which may indicate that a large amount of firms' effort to surround their own patents derives from patents filed after the innovation is introduced/ used.

Table 34 –Number of Follow-up Patent Applications for Typical Product and Process Inventions
(as percentage of respondents assigning each category)

Number of follow-ups	Type of invention	
	product	process
From 1 to 2	65	67
From 3 to 4	26	27
From 5 to 6	4	0
From 7 to 8	0	0
From 9 to 10	4	7
More than 10	0	0

Regarding follow-up patent applications, our survey detected i) how many of them are filed per priority filing[190] (Q.B16), and ii) how far from the priority filing date they are applied for (Q.B18). Firms reported how many follow-up applications are filed with respect to both product and process inventions. Six options were given, and the overall percentage responding to each category is shown in Table 34. The findings suggest that, on average, not many follow-ups are filed per priority application.

Table 35 – Number of Follow-ups Used by Complex and Discrete Firms for Their Typical and Most Valuable Product Inventions
(as percentage of respondents assigning each category)

Number of follow-ups	Product invention			
	Complex		Discrete	
	Typical	Most valuable	Typical	Most valuable
From 1 to 2	82	33	50	30
From 3 to 4	9	56	42	40
From 5 to 6	9	11	0	0
From 7 to 8	0	0	0	10
From 9 to 10	0	0	8	10
More than 10	0	0	0	10

[190] The first application claiming priority on the invention.

A further investigation (Table 35 and Table 36) by industry suggests that firms in the complex industry use fewer follow-ups than firms in the discrete industry, which might be a result of the shorter innovation development time in the former. The results also point out that the most valuable inventions tend to have more follow-ups than typical inventions.

Table 36 – Number of Follow-ups Used by Complex and Discrete Firms for Their Typical and Most Valuable Process Inventions (as percentage of respondents assigning each category)

Number of follow-ups	Process invention			
	Complex		Discrete	
	Typical	Most valuable	Typical	Most valuable
From 1 to 2	80	50	60	11
From 3 to 4	20	50	30	44
From 5 to 6	0	0	0	11
From 7 to 8	0	0	0	22
From 9 to 10	0	0	10	0
More than 10	0	0	0	11

Follow-ups were detected to be filed mostly no later than 12 months from the date of the priority filing, though a considerable amount of follow-ups are still applied for between 12 and 18 months from the priority filing (Table 37). As this is a period when the invention is approaching its launch on the market, based upon the average innovation development time reported earlier, it is unlikely that improvements at that time are out of the scope of previous applications. However, if further improvements are patentable, firms may decide to follow up.

Table 37 - Average Percentage of Follow-ups by Timing of Application

Timing of follow-ups application	mean	s.e.
Within 12 months from priority filing	44.52	7.08
Between 12 and 18 months from priority filing	21.19	4.12
Between 18 months and the issuance of the patent corresponding the priority filing	9.52	1.82
After the issuance of the patent corresponding to the priority filing	10.71	3.03

7.3 DISCUSSION

In this section, we discuss the findings above and link, whenever possible, our results to the existing literature. We begin by highlighting some characteristics of our survey sample that should be borne in mind. Then, we compare patents *vis-à-vis* other methods of appropriation, and discuss why (or not) firms apply for patents. The third point addressed regards the decision-making process of the construction of patent portfolios. At last, we analyse the results concerned with firms' patent policies.

7.3.1 *INITIAL REMARKS*

The results produced from responses to our survey come from a population that consisted of the largest R&D spenders in UK manufacturing. Another important point that should be considered when interpreting the results is the distribution of R&D expenses. Although the share of R&D expenses allocated to applied research[191] and design/ development[192] are (statistically) about the same (40%), there is a variation across industries. Discrete firms said they

[191] Defined as scientific or engineering research with a specific commercial objective.

[192] Defined as technical activity translating research findings into products or processes.

allocate more resources to applied research whereas complex firms reported that they spend more on development (or design) activities. The variability in that distribution may reflect their patenting behaviour.

7.3.2 APPROPRIABILITY

Previous survey-based studies have attempted to capture the relative importance of patents by asking either how effective patents are, or for what share of innovations patents are effective in protecting competitive advantage. The findings suggest that there exist differences across countries, and also that inter-temporal changes may happen.

Our survey asks about the proportion of innovations for which returns are increased due to different methods of appropriation. As in previous studies (e.g., Cohen et al. 2002), such measures allow one to detect the frequency with which a method is employed, and to also identify the usefulness of that method in helping firms appropriate rents from their innovations. In addition, there is an advantage of not restricting responses on how an appropriability mechanism can increase returns. We have addressed elsewhere in this thesis what makes firms perceive patents as more (or less) important for protective purposes. The results from our survey, however, focus on the importance of patents as a means of increasing the returns[193] from innovation, which may not necessarily rest with protection. This is particularly useful in the case of patents, which can

[193] Returns not achieved in the absence of a particular method of protection.

be used, for example, as a means of facilitating licensing-out or a means of attracting contracting partners.

Table 38 compares our results to previous findings by showing the rank-order of each mechanism by each study. Not all mechanisms are reported because the lists were not always the same nor were the lists formulated in the same way or the response scale employed the same across the studies summarized in Table 38. The results are presented in rank order to facilitate interpretation.

Table 38 – Rank Order of Importance of Mechanisms of Appropriability for Product Innovations

	Levin et al. (1987)	Harabi (1995)	Granstrand (1999)		Cohen et al. (2002)		Current based upon CIS[a]	Current based upon patent survey
Period	Early 1980's	Late 1980's	Early 1990's		Mid 1990's		Late 1990's	Early 2000's
Country	US	Switzerland	Japan	Sweden	US	Japan	UK	UK
Response scale	1-7	1-7	0-4	0-4	%	%	0-3	%
Sample (n)	650	358	24	24	797	567	3440	46
Learning Curve	3rd	3rd	2nd	2nd	3rd	3rd	n.m.	4th
Lead-time	2nd	1st	3rd	3rd	1st	1st	1st	2nd
Patents	**4th**	**5th**	**1st**	**5th**	5th	**2nd**	**4th**	**1st**
Secrecy	5th	4th	5th	4th	2nd	5th	2nd	5th
Superior marketing	1st	2nd	3rd	1st	4th	4th	3rd	3rd
Switch costs	n.m.	n.m.	6th	6th	n.m.	n.m.	n.m.	6th

[a] Full sample.
n.m.: not measured.

It seems that patents are most valued in Japan, although our patent survey (UK) has indicated a higher importance of patents in comparison to others mechanisms. It might be that the results are not totally unexpected given the nature of our sample (mostly firms that use patents) and respondents (personnel in charge of patents), which may have biased our results towards those to whom patents are more important. As shown in Table 4 the results on the importance of patents change drastically when the sample from the Community Innovation Survey is restricted to those firms that use this type of method of appropriation.

Similar to the sample of the patent survey, patents play a more prominent role for those firms in the CIS sample who made use of them. Although at first glance it seems obvious that patents are valued more by those who use them, it does not mean that patents have to be more important than other methods. It might be that it is a result of respondents 'relativising' when answering the questions. That is, as patents are deemed of higher importance, this has to be at the expenses of other methods being of lower importance. However, we have found in the patent survey that the contribution of patents with respect to product innovations is not statistically different from that given by lead-time and superior marketing/ sales effort. This suggests the crude rank-order used in Table 38 may not be appropriate if one wants to address a more robust cross-country comparison. A more sophisticated analysis is needed before conclusions, which with the data available is not possible.

Although previous surveys (e.g., Cohen et al. 2000; Harabi 1995; Levin et al. 1987) have addressed comparisons between patents and other mechanisms of appropriability, they have not drawn attention to the skewness in the distribution of the value of innovations. At most, they have contrasted the importance of patents for product and process innovations. Our survey has moved forward by approaching that issue in both ways. We have detected that the use of patents seems to be less extensive in reaping the benefits of process innovations than product innovations, which is in line with previous studies (e.g., Cohen et al. 2000; Levin et al. 1987). In addition, our results suggest that the returns from process innovations are perhaps higher when firms are able to control manufacturing capabilities and secrecy. Moreover, in showing that patents can be as important as lead-time and sales and service effort the results for patent survey indicate that patents can add sufficient value at the margin to the strengthening of firms' overall appropriability condition, at least with respect to product innovations.

In addition, our survey has also detected that firms perceive the share of the most valuable patented product and process innovations to not statistically differ. This suggests that although product innovations can be patented more often than process innovations, patents might not be more important to product than to process innovations. This new finding contrasts with current knowledge. It might be that the specific question of our survey instrument was not able to portray that phenomenon properly, but we conjecture that the results from Table 25 give support to this finding. That table reveals that the difficulty in detecting infringement is, if not the most, then at least one of the most important reasons for firms not to patent process inventions. This can generate different patents (products/ processes) distributions and hence can mask the real importance of patents to both types of innovations.

We have also found that patents are equally important in increasing the returns from innovations of complex and discrete industries. However, the most valuable innovations of the discrete industry appear to rely more on patents than the most valuable innovations of the complex industry. Because of mutual dependence, firms in the complex industry may judge that the benefits accruing from patents are mostly indirect. That is, their patent portfolios might improve their position in negotiations with other firms, but do not give them complete autonomy. This could partly explain why, although they have an equal proportion of their innovations protected by patents, compared to the firms in the discrete industry, firms in the complex industry perceive that patents have a lower impact on the returns to the most valuable innovations. Nevertheless, we found no evidence that firms in the complex industry use their patents more extensively than firms in the discrete industry to access other firms' inventions. This casts doubt on that argument. It might be that the distribution of R&D expenses justifies this phenomenon. We observed earlier that discrete firms in our survey sample spend more on applied research than on development activities. Complex firms, in turn, follow the opposite way. It might be therefore that the longer term, and perhaps larger, R&D investments that generate the most valuable innovations in the discrete industry (compared to the complex industry) demand more time to recoup. Thus, the relatively longer monopoly power of patents may be more adequate for the most valuable innovations of that industry, whose investments in their generation are likely to be under higher risks and uncertainties.

Although the extensive role played by patents is now recognized in the specialized literature, few attempts have been made to explore the motivations underlying firms' patent behaviour. Harabi (1995), for instance, studied the relevance of a number of motives Swiss firms had to be interested in patenting. His results indicate that patents are more relevant to secure licensing revenues, to prevent duplication, and to achieve a more favourable position in negotiations with other firms. Cohen et al. (2002) asked US and Japanese firms their reasons to patent and drew conclusions on the basis of the frequency of each motive. The reasons most frequently cited by both US and Japanese firms were: to stop copying; to prevent rivals from patenting related inventions; and to avoid legal conflicts. But Japanese firms also reported to apply for patents driven by their interest in a better bargaining position in technology negotiations. Although this was the fourth incentive most frequently cited by Japanese firms to pursue patents, this was cited more often than the second most cited reason by US firms (i.e., patenting of related inventions by rivals). We took a slightly different approach and asked the proportion of patent applications that were filed according to a number (larger than earlier studies) of factors. This would give a better visibility of the relevance of the reason and the extent they induce patenting. Our findings match the results found for the US and Japan, i.e. firms' major concern is with copying of their inventions. Other reasons our sample reported to seek patents were: to avoid copying of similar invention; to prevent other firms from patenting variations of the invention; and to increase inventing around costs. Similar to American firms and different from Japanese and Swiss firms, the interest of our sample in holding patents to have access to other technologies seems to be low in comparison to the chief motivation (i.e., to stop copying).

Cohen et al. (2002) also investigated how the reasons vary by industry type. They found Japanese firms behave more similarly across industries than US firms. Despite our initial evidence suggesting similarities between our sample and US firms, we found that our sample firms are equally likely to patent for most reasons across industries. The only (robust) statistically significant difference between complex and discrete firms regards the proportion of patent applications filed with the purpose of increasing competitors' inventing around costs, which our findings indicate to motivate more complex firms than discrete firms.

Granstrand (1999) observed that large Japanese corporations are more constrained by the costs of patenting than by the disclosure of information in a patent grant. Harabi (1995) gave more alternatives to his sample of Swiss firms and also addressed a comparison between types of innovation (i.e., product *vs.* process). He found that for both product and process innovations the possibility of rival firms inventing around patents is the major concern of Swiss firms followed by the excessive information disclosed in a patent document, though no option of patenting costs was offered. Cohen et al. (2000) observed that, like Swiss firms, patenting by US firms is hampered mainly by the ease with which patents are invented around. The authors also found that the difficulty in showing the novelty of the invention was reported to be the second most important reason for US firms not to apply for a patent, followed by information disclosure, and costs of patenting. They extended that analysis to Japanese firms and a cross-country comparison identified that patents serve the technical information diffusion function more effectively in Japan than in the US since Japanese firms deem information disclosure to affect their patenting more seriously than US firms judge (Cohen et al. 2002).

Our survey adds to the above by not only providing new evidence for another country but also by providing new findings of factors hampering patenting across innovation type and, especially, across industries. Our results (Table 25) for the UK confirm to a large extent the Swiss and US findings that the ease with which a patent is circumvented is the chief factor firms perceive for not pursuing patents, especially if the innovation is a product. Process innovations have shown a different pattern and, as reported earlier, non-applications are mainly driven by the difficulty in detecting infringement. Complex and discrete firms were found to differ in, at least, three aspects with respect to the reasons for not filing patent applications. A larger proportion of complex firms (compared to discrete ones) is affected by 'the ease of inventing around' and 'the uncertainty as to the validity of the patent'. Discrete firms, in turn, are more affected by disclosure of information, especially when the innovation is a product.

Although information disclosure appears to affect more one industry than another, in both industries the information from patents is obtained with equal purposes in mind. Our findings indicate that patent information is mainly used to check whether an invention was already patented. The use of patents as a source of technical information was detected to be one of the least important reasons. Although it seems paradoxical the evidence that information disclosure is to a certain degree a factor that hampers patenting but at the same time firms do not make much use of that information, one should remember that this evidence derives from large R&D spenders. That is, our sample firms are likely to be at the frontier of knowledge and the technical information disclosed by patents might be outdated to them. This means that although the role played by patents in diffusing information across rivals is apparently limited, which would be of concern to policy makers, this might not be a problem as serious as it seems to be; but certainly more investigation in that direction is needed.

The fact that complex firms are more influenced by the risks of their patent being invalid may have to do with either the technology life cycle (where mature technologies are perhaps more difficult to prove valid if contested due to the extent of the prior art) or the higher risks of litigation in this industry as compared to the discrete one. It could be that, overall, the UK complex industry deals with a more mature technology. However, no inter-industry difference was found as to the fulfilment of the patentability criteria during the prosecution of a patent application, which casts some doubt on the life cycle hypothesis. Moreover, the costs of defending patents in court was not found to influence differently complex and discrete firms, and thus the higher risks of litigation hypothesis is unlikely.

Perhaps the justification why complex firms are more (negatively) influenced by the risks of their patent being invalid and the ease of inventing around rests with the distribution of R&D expenses across industries. Complex firms rely more on development activities than on applied research; the opposite applies to discrete firms. It is likely therefore that the technological content of the innovations created by discrete firms is higher, and thus their corresponding patents are perhaps more difficult to invent around (due to higher costs) and easier to prove validity. This may also justify why complex firms reported to file a larger share of patent applications in order to increase rivals' inventing around costs. In parallel, as the information obtained from applied research is likely to be more valuable than the one derived from development, information disclosed by patents of the output of the former activity is likely to affect more seriously those who spend more on that activity, i.e. discrete firms.

7.3.3 CONSTRUCTION OF PATENT PORTFOLIOS

Empirical studies on patents have drawn attention to appropriability conditions, why (or not) firms patent, and what firms do patent (i.e., product or process inventions). However, patent portfolios are not produced only on the basis of the decision to patent a particular invention. Several decisions are taken, amongst them at what time a patent will be applied for; and where a patent will be taken out (if the application is successful). The decision as to when to file a patent also influences to a certain degree what will be patented due to the information available at that time. Despite the scant attention given to those decisions by the academic literature, they are central to firms' proprietary control of their knowledge assets and thus we have explored them in our survey.

Decisions on where to patent are likely to be taken with several factors in mind, such as the legal environment, the nature of technology, the market structure, the application costs, to name but a few. Bertin & Wyatt (1988) found that the main reason driving the choice of the country by multinationals was the existing or the prospect of business in the country. Firms in their survey reported to apply for patents mainly in the US, Japan, Germany, UK, and France. Grupp & Schmoch (1999) used patent statistics to evaluate the main countries where patents were applied for. They also found those countries as the largest recipients of patent applications. Our survey results on where firms patent seem to be in line with those studies.

Although the UK was reported to be the country where most patent applications are filed, this is not unsurprising. Grupp & Schmoch (1999), for example, also detected on the basis of a case study of a German company that most of its patents were filed in its home country. Although our survey does not investigate why the home country is the largest recipient, we suspect this is intuitive. Moreover, the legislation may influence that phenomenon; as the UK law demands inventions created in its territorial domains to be first filed in the UK Patent Office it is likely that our sample firms apply first to the UKPO and then decide later in which countries the application will progress; especially because our sample firms carry out R&D activities in the UK. In addition, most countries are signatories of the Paris Convention and thus the priority application filed in the UK Patent Office can be filed in those countries within 12 months from the priority date. By that time they may have a better idea whether the invention will be commercialized in other countries or just in the UK. Our interviews within pharmaceuticals (chapter 3) suggest that when speed of the prosecution of the application is also needed firms may focus on the UKPO only. It might be that specific characteristics of the market and/ or a quicker publication also drive applications to the UKPO only. Quicker publication is sought to avoid anyone else securing property rights on a similar invention (i.e., novelty requirement will not be met). Although firms can use other means of disclosing their inventions, in choosing to apply for a patent they can assure that, assuming that the application is successful, they will be able to enforce property rights if they realise later that the corresponding invention is valuable.

Our findings indicate that applications were reported to be motivated mainly by the economic prospects of the invention, which corroborates what Bertin & Wyatt (1988) found for multinationals. This suggests that patents taken out in countries where firms operate, or foresee participating (e.g., producing, exporting, licensing) in the near future, are likely the most valuable patents. If firms do not envisage doing business in the near future in a particular country, it is likely that they will apply for a patent in that country if the size of the market justifies patenting expenses because, even if they do not think of a participation there in the near future, it might be a market of interest. Our results also suggest that a relatively large proportion of filings abroad happens because of the presence of main competitors in the market. Perhaps even if the market is not very large and the firm does not operate there the presence of the main competitors means the existence of a market that can be explored and, at least, it is an option that should be kept available. It is likely therefore that a vast patent family covers at least those three elements. This means that the size of a patent family might be related to the value of a patent, even if this relationship is not linear as observed by Guellec & van Pottelsberghe (2000). In fact, the authors found that patenting in a large number of countries is not needed; protection in the largest markets and economies of scale might suffice.

We also detected that the enforcement climate of the country plays a more important role for discrete firms than for complex firms. As discrete firms in our sample place more value on using patents to have access to foreign markets than complex firms do, that result is not surprising. Interesting perhaps is that although our sample firms reported that the costs of application are one of the most important reasons they do not apply for patents, the percentage of foreign applications motivated by lower costs is relatively small. Interviews with pharmaceutical firms suggest that the PCT and the EPO routes are used very often and thus, although costly, they are on many occasions cheaper than choosing individual countries, especially because the pharmaceutical firms we interviewed reported that they tend to choose a number of countries that make those routes economically favourable.

Territorial coverage is one dimension of patent scope, which also embraces the breadth of the intellectual property rights. The scope of protection is therefore an instrument of concern for policy makers (Klemperer 1990). Although patent offices rule the extent to which intellectual property rights are granted, the scope of a patent is also determined by the inventors own actions. Lerner (1994) identified that scope is positively related to market value. We have seen that portfolios are pursued with broader protection in mind, though we have noticed that valuable innovations can also be under proprietary control by the means of a narrow patent. This contrasts to a certain degree to the findings of Lerner (1994). We conjecture that one possible explanation for such different results rests with technology life cycle. Lerner (1994) concentrated upon the biotechnology industry, which is still an emerging industry and the focus is mainly on product innovations. More mature industries may value process innovations more than newer industries. In this case, even if narrow, a patent of the low cost production process is valuable. As we found that complex firms value narrow patents more than discrete firms do, does it mean that the complex industry is more mature than the discrete industry? Our ability to empirically probe this argument is void. However, if technology life cycle is not the chief reason, perhaps there is, again, a role to be played by the distribution of R&D expenses. If the technology in the complex industry is not more mature than the technology in the discrete industry, one would expect firms in both industries to pursue equally broad patents. As this was not observed, it might be that firms in the discrete industry, by relying more on applied research, are more capable of broadening the scope of their patents due to the nature of the output of their R&D effort. One could argue that size effects lead to inter-industry variability since the size distribution in complex industry is biased towards smaller firms. However, we have examined statistically that size and industry are independent (Table 19).

Another possibility for complex and discrete firms to differ with respect to the scope of their most valuable patents could be the time at which they file patent applications. If discrete firms apply for patents later than complex firms, they might carry out more experimentation and hence have more information available to substantiate the claims in their applications. Nevertheless, our results do not support this idea. Our survey results indicate that firms in complex and discrete industries tend to apply for patents, on average, at about the same moment along the innovation process, that is, around one third of its total length. Thus the only explanation available for inter-industry differences in scope of most valuable innovations resorts to the distribution of R&D. Our results also suggests that although the distribution of R&D expenses may influence the (average) length an innovation takes to be created and commercialized (shorter in the complex industry), it does not seem to affect the moment the priority application is filed (proportionately).

Despite previous evidence (e.g., Pakes 1985) indicating that patents are applied for early in the innovation process, there is no empirical evidence, at least to the best of our knowledge, showing what 'early' means. Our survey fills this gap by finding that the first patent application is filed after one third of that process has come to an end. Furthermore, our findings also indicate that we should be careful when announcing the 'early-bird' nature of patents. We found that follow-up applications can be filed and they may not necessarily be just after the priority application. Although most of the follow-ups are filed within 12 months from the priority filing, a residual is applied for later. We also detected that the number of follow-ups does not seem to vary according to the type of innovation. However, inter-industry differences were observed. The complex industry was found to account for a smaller number of follow-ups when compared to the discrete industry, perhaps as a result of the shorter length of its innovation process. Nevertheless, in both industries the most valuable patents seem to have more follow-ups than typical patents. Our interviews within pharmaceuticals revealed that follow-ups not only help in broadening the scope of the innovation launched on the market but also help in 'extending' the life of the priority patent. Follow-up applications, however, were not found to be the norm[194] in UK manufacturing, but our empirical work could not go further in identifying exactly why, though we suspect that the degree of innovativeness as well as firms' patent policies can partly explain.

7.3.4 *PATENT POLICIES*

Although the categories of patent policy (Table 24) used in our survey instrument are not mutually exclusive, they may reveal the extent to which patents are pursued. The findings confirm that process innovations are less likely to be patented than product innovations. Moreover, according to our

[194] Due to the number of respondents that left the question blank.

findings, there seems to be a threshold beyond which firms are less likely to devote resources to patenting.

Thumm (2001) observed that European biotechnology firms patent intensively. Our survey has identified high-tech firms as those whose patent policies are oriented towards patenting as much as possible, and thus seems to support Thumm's findings. This type of patent 'strategy' is referred to in the literature (e.g., Granstrand 1999; Knight 1996) as 'flooding' or 'blanketing' and is suggested to be more commonly used by firms in R&D-intensive technology fields. What is yet to be learnt is the effects of this strategy on welfare. Heller & Eisenberg (1998) have already drawn attention to what they call the 'tragedy of the anticommons'. Their concern is that excessive patenting may lead to underused resources, and hence not to be welfare enhancing. Kitch (1977), in turn, argues that patents on early prospects may save resources from being wasted and may guide future developments. This 'excessive' patenting may be a result of an emerging technology field where firms seek not only to hold a higher stake but also to avoid being locked out. It is difficult to predict from the information collected by our survey instrument whether or not that practice is welfare damaging.

We found, at least on the basis of the studied sample, that firms pursue patents mainly with exclusionary purposes in mind (Table 26). Our results indicate that about 30% of the innovations are patented motivated by the possibility of creating a source of revenue by licensing-out in contrast to the nearly 70% of innovations patented to preclude others from copying them. If the exclusionary behaviour prevails to the extent that innovations are unexploited when they could be, welfare losses may indeed be higher. However, most firms reported to be prone to patent what might not be in their direct interest but rather in other firms'. So, excessive patenting may not be so harmful to welfare, but it would be too premature to say so on the basis of these findings.

What perhaps can give rise to concerns about the effects of the patent system is that patents do not seem to be an appropriate channel of knowledge spillovers. Firms did not rank patents highly with regard to the usefulness of the technical information disclosed (Table 27). As the objective of exerting monopoly power seems to be the driving force underpinning patent filings, and if the role of patents in the diffusion of information is somewhat limited, welfare might be compromised. We have argued earlier that the limited usefulness of the technical information disclosed by patents might be because these firms are the ones that are at the frontier of knowledge in their technology fields for which patent information can be, in fact, less useful since it is disclosed only 18 months after the priority date. Moreover, as patents tend to correspond to firms' technology paths[195] the information can be more useful for those lagging behind. We observed that complex firms spend more on development activities than on applied research and the opposite for discrete firms. However, we found no inter-industry differences in the usefulness of

[195] Only a marginal share of innovations were said to be patented to disguise firms' real interests.

patent information. This leaves the answer to that phenomenon obscure and demanding further research.

It is more likely that negotiations will arise when there are complementary patents. The firms studied reported that they hardly ever pursue inventive activities with the purpose of overlapping someone else's patents to force negotiation. Only a marginal proportion of applications was said to be consciously designed to surround other firms' patents in order to induce them to a deal. Perhaps because of the 'absence' of this patent strategy that firms reported the ease of being induced to cross-license as the least important factor hampering their patent applications. Firms also reported that the filing of patent applications with the objective of avoiding infringement trials is not a common practice, and that the costs of legal disputes are the second least important factor affecting their decision not to apply for patents. Although these may suggest that firms are keen on going to court, earlier evidence (i.e., no overlapping patents) suggests the contrary. In fact, in describing what they use patent information for, firms revealed their main interests in checking if an invention has already been patented and if they are not infringing someone else's patents.

Their concern about infringing other firms' patents parallels the exclusionary purpose underlying their patenting behaviour. Similar to US firms and contrary to Japanese ones (Cohen et al. 2002), firms in the UK seem to place more value on exclusion than on reciprocity, although Collinson et al. (2005) have identified Japanese firms to be moving away from reciprocal market mechanisms. However, firms in the US complex industry seem to use patents to negotiate with other patent holders than firms in the US discrete industry do (Cohen et al. 2002; Hall & Ziedonis 2001). Thus, the exclusionary intent reported by firms in the complex industry could be thought surprising as there is no difference (statistically) from the firms in the discrete industry. We conjecture that firms are only able to use patents as bargaining chips if the corresponding patent is strong enough to persuade other agents not to either circumvent it or challenge it. Thus, regardless of their industry firms need to build a strong patent position (in exclusionary terms) to exploit further uses of patents. However, it is surprising that the composition of firms' patent portfolios do not statistically differ (Table 33).

Reitzig (2004b) has observed that patent thickets can be found in both complex and discrete industries, which our findings seem to support (even if the size of the thickets are small). However, firms' patent portfolios seem to be more characterized by fences than thickets. This is based not only on the proportion of patents that surround patents held by other competitors, which seems to be small, but also by firms' 'court-averse' behaviour. What might be interesting is that, according to our sample of UK manufacturing firms, despite the US being the largest market of interest, after the UK, firms do not seem to pay attention to that practice, which seems to be relatively common there (Cohen et al. 2002).

Most respondents said that despite being keener on a broad patent, the majority of their patent portfolios consist of patents surrounding their own patents and patents covering an array of technical solutions. Both the former ('surrounding') and the latter ('fencing') strategies are to some extent a result of continuous patenting, where follow-ups are filed mainly within 18 months from the priority date in order to take advantage of no prior art that is yet to be disclosed by the first application (priority application). As observed by Granstrand (1999) this is a practice that may enable firms to 'extend' the patent life and hence increase the returns from the innovation, but that may not be of interest for those whose innovation life cycle is too short. Although we cannot assert that innovations from the UK complex industry have, on average, a shorter life cycle than innovations from the UK discrete industry, we suspect this might happen, at least for our sample firms. The shorter period to launch an innovation on the market and the main innovation activity developed by complex firms (i.e., development or design) are reasonable indicators to support our suspicion. Moreover, as the period of the patent life up to which complex firms are inclined to defend against infringements is shorter than the one reported by discrete firms, it is likely that innovations in the former industry become obsolete faster than in the latter. These findings contrast with the belief that patent renewals can indicate the value of a patent, that is, the longer the life of a patent, the more valuable that patent is. There seems to be an optimum patent life after which the costs of defending the patent in court are not justified. Our conversation with personnel in pharmaceuticals revealed that firms may realise that it might be more advantageous to invest in other activities than to incur legal costs.

The exclusionary approach of UK firms is supported by the way their patent portfolios are designed. Despite the 'surrounding' strategy being the most used, according to our results, there seems to be a relatively flat distribution of patent 'strategies'. Moreover, our findings do not indicate any variability across industries or across policies. Our results suggest that complex firms are keener on prohibitive inventing around patents (i.e., 'strategic' patents) but the proportion of this type of patent that they hold is not different (statistically) from the proportion held by discrete firms. The greater interest by complex firms in that type of patent might be a consequence of designing around patents being easier in that industry, as our findings suggest. All in all, our results indicate that it is very unlikely that firms' patent portfolios are structured in a single way; a combination of designs exists. Moreover, as firms perceive the costs of patenting being high they do not seem to be interested in keeping patents in force to mask their real technological interest. Perhaps the benefits of showing their true technological competency (e.g., licensing, partnering, merger) outweigh the benefits of not revealing it (e.g., competitors investing in low value technological areas).

As mentioned earlier our results suggest that the distribution of R&D expenses may influence the degree of appropriability achieved. This means that the effectiveness of patents as a means of protecting value is perhaps proportional to the effort devoted to the creation and capture of that value. Our results also suggest that the use of patents strategically with respect to information manipulation is hardly ever employed with the purpose of dissuading competitors. It might be that the benefits of doing so are so small they do not compensate for the costs or risks involved, despite firms reporting that patents are relatively high important in their analysis of rivals' technological competence. On the one hand, the more frequent use of patents as a tool for competitive analysis may be a result of recent developments of media and software services in that area. Although firms may have perceived that the use of patents for that purpose has grown, they may have not perceived how to use that practice to influence other firms' behaviour. On the other hand, R&D activities are increasingly costly, which has made firms more selective with their projects and upon which they will employ their budgets. As a result, it is unlikely that they will devote resources and time to patenting inventions to dissuade competitors when they could be patenting inventions that are more likely to bring tangible returns.

7.4 CONCLUSIONS

This study empirically explores appropriability conditions in UK manufacturing and how patent portfolios are produced on the basis of firms' decision making re why, when and where they patent. Our findings derive from responses to a new questionnaire sent to manufacturing firms listed on the UK *R&D Scoreboard*. The 12% response rate achieved generated 46 usable questionnaires. Our sample, despite being small, has a high degree of match with the survey population and thus can be considered representative.

Although our investigation on the appropriability conditions in the UK reveals that patents play an important role we suspect that this is a consequence of the sample which was purposefully selected to comprise only firms that use patents. Our earlier findings (chapter 4) are perhaps more appropriate to detect how important patents are in UK manufacturing. However, our survey provides several insights on how patents are produced and some surprising results.

One of the salient results regards the importance of patents to protect product and process innovations. Our results confirm previous studies which show that product innovations are more often patented than process innovations. Nevertheless, we have also found that the most important innovations are equally patented regardless of their type (product or process). Moreover, one of the most important factors that hampers firms from patenting process innovations was found to be the difficulty in detecting infringements. Although it is intuitive that process innovations are more difficult for rivals to have access, and hence to imitate, our results suggest that not all valuable process innovations are kept secret. If the process innovation is perceived to be valuable, it can be patented as much as the most valuable product innovations. This, contrary to our existing knowledge, indicates that patents might be as important to process innovations as they are to product innovations.

One immediate implication of the above result is that certain process innovations, by not being patented, are less likely to be publicly disclosed and hence have their diffusion restricted. One the one hand, despite the recent change in the onus of the proof (now requiring potential infringers to prove they are not infringing third parties patents), this does not seem to be enough to persuade inventors to patent more frequently process innovations, and thus changes to patent policy might be necessary. On the other hand, as the non-patented process innovations are not the most valuable innovations, perhaps what is kept secret does not seriously affect welfare. But this needs more research.

Our results also show that concerns about R&D spillovers produced by patents should not be restricted to process innovations. We found that patent information for competitive analysis is rated comparably higher than patent information for (technical) problem-solving; the latter is expected to help in the diffusion of knowledge. Our ability to empirically support that more attention should be given to the role played by patents in diffusing knowledge is limited. We have not observed how important patents are, in comparison to other ways (e.g., conferences, trade associations), as a channel of information flow. But we could observe that despite being keen on licensing-out, the proportion of patents applied for motivated by partnering (e.g., standard-setting, R&D co-operation) is relatively low. As these are also ways of promoting information sharing across firms, perhaps the ability of patents in diffusing knowledge is, in fact, limited. But then, again, more research is needed.

Our findings revealed that the patent system in the UK is mainly used for exclusionary purposes. This is similar to what Cohen et al. (2002) found for the US and Japan. However, the authors detected that Japanese firms, contrary to US firms, also use patents extensively in negotiations. Our results, at least for the sample firms, indicate that UK firms behave in this respect closer to US firms than to Japanese ones. However, different from US firms and similar to Japanese ones, our results revealed that UK firms when split into two industries (complex and discrete), on the basis of the number of patentable elements of the final innovation, do not show inter-industry variability regarding the extent they use patents for negotiations. And our findings also suggest that the extent to which UK firms use patents in negotiations seems to be lower than US and Japanese firms do. This may reinforce earlier evidence that perhaps more attention should be paid to increase the UK patent system's capacity to promote knowledge sharing. Whether or not the UK patent system is less socially desirable than the US and the Japanese patent systems is not clear from the results available; this requires further and more extensive empirical investigations. As suggested by Cohen (2002) there might be cross-national differences in, for example, managerial practices, market structure, and technological content that may explain these differences (or similarities), which with the data available is difficult to conclude.

In addition to the above our results indicate that the distribution of R&D expenses may affect firms' patenting behaviour. Firms that work in industries where the final innovation comprises several patentable parts (complex industry) were observed to spend more on development activities than on applied research. These firms were found to seek patents with high inventing around costs more often than firms whose final innovations consist of a relatively smaller number of patentable parts (discrete industry). Nevertheless, according to our results, the former does not seem to achieve that purpose more frequently than the latter. Complex firms also reported that a larger proportion of inventions, in comparison to discrete firms, were not patented because of the risks of the patent not being valid or being invented around. Moreover, compared to discrete firms, complex firms reported that a larger proportion of their most valuable innovations are protected by narrow patents. We conjecture that this behaviour mirrors the output of R&D. In spending more on development activities than on applied research, firms in the complex industry are perhaps more likely to generate innovations of lower technological content, and thus, if patented, easier to be circumvented or invalidated, and whose scope is narrower than patents generated from innovations derived from applied research. Consistent with this observation, we detected that the innovation process in the complex industry is shorter than it is in the discrete industry. As approximately 90% of our sample firms reported to have their head office in the UK, these findings perhaps give rise to concerns about the competitiveness of the UK complex industry, an issue upon which policy makers should draw more attention. In particular, because firms in both industries reported that patents are central to increase their returns from innovation.

The results from our survey suggest that the chief reason leading firms to patent abroad is the economic one, and the first option is for markets where they already participate or predict to join. This extends the findings previously observed for multinationals (e.g., Bertin & Wyatt 1988). The findings also revealed that, on average, firms apply for a priority application after one third of the innovation process has come to an end, regardless of the industry. On the one hand, this result supports existing knowledge that patents are applied early in the innovation process (e.g., Pakes 1985). On the other hand, it does not stand alone because follow-ups can be filed and, even if not vastly used, they may be applied for later in that process.

A few academic implications are in order. On the empirical side, studies have attempted to validate patent indicators in many ways. For example, Lerner (1994) observed that in biotechnology patent scope and firm's market value are positively correlated. Our results indicate that broader patents seem to be more valuable than narrow ones, but that narrow patents can be valuable as well. As Lerner's (1994) analysis comes from a single and emerging industry and our evidence is based upon an inter-industry comparison, we think this difference may rest with technology life cycle. Perhaps industries governed by more mature technologies have extensive prior art, which makes more difficult to obtain a broad patent. In parallel, more mature industries may value process innovations more than emerging industries, especially cost-reducing processes. Another reason might be that a broader patent scope increases the likelihood of a patent being challenged. Patent scope therefore might not be unambiguous and thus should be dealt with more carefully for patent valuation purposes.

Another indicator assumed to be positively related to the economic value of a patent is the patent family. Supra national routes (e.g., PCT) have provided patenting procedures to allow for later decisions as to whether the application will progress in a certain country. This makes it difficult to foretell the extent the application is valuable, especially if this is a priority application applied earlier in the innovation process, as suggested by our results. However, if one employs patent grants, as opposed to patent applications, when using patent families to measure the value of patents that rationale might not be incorrect. As the driving force guiding foreign patenting is the economic one, it is likely that the larger the patent family the more valuable a patent is. However, there is still some noise in that analysis because patents, even if from the same family, are granted at different points in time, according to the patent systems' work load.

In addition, our findings indicate that firms are interested in defending their patents for most of their possible life. Although this suggests that the payment of renewal fees is a good *proxy* for the value of a patent, a degree of caution should also be exercised. There might be variability (at least we found inter-industry differences) in how long the enforcement of a patent is justified. Moreover, there seems to be an optimum patent life after which the costs of defending the patent in court are not justified, though the patent can be kept in force. Furthermore, the use of follow-ups may overshadow which patent is really the most valuable. Although the priority patent will be older than the follow-up patent, the latter may become the real protection of the final innovation, and the former only a supplementary protection that will help in making things more difficult for late comers.

On the theoretical side, our results indicate that the usefulness of the patent system seems to depend, amongst other things, on the degree of innovativeness. The distribution of R&D expenses may affect this degree to a certain extent. For economic theory, our findings touch at various levels the theories on the patent system summarized by Mazzoleni & Nelson (1998a, b). But perhaps the most prominent result is the one that indicates that even devoting more effort to the development stage firms are able to patent. This seems to be contrary to the second theory described by those authors, which assumes that follow-on work is not patentable. However, firms' ability to leverage their competitiveness seems to be more limited for those who rely on those patents. Another point is that, contrary to what we expected, our results are not conclusive as to which element of patent design is the most important one. Patent scope and length seem to work hand in hand when firms take their decisions, and thus we cannot, on the basis of our study, suggest academics and policy-makers to devote more time and effort to a particular element. A final point regarding economic theory is that our findings indicate that patent information is rarely used to dissuade rivals, and thus it is unlikely that firms will not pay renewal fees in a strategic context (i.e., not to call attention of competitors for a particular market), even if it happens it seems to be a very rare event, at least in a competitive market like the UK's.

For strategic management theory, the results suggest that the ability of a patent to influence other firms is concentrated more on what it really is, i.e. a delimitation of the boundaries of the technological space (by holding property rights), rather than on what it could be, i.e. a mechanism to mislead competitors as to the true technological trajectory of the innovator or his/ her real interest in a market (by holding patents on inventions that will not be explored and by stopping paying renewal fees, respectively). Our findings suggest that the effectiveness of patents as an isolating mechanism depends to some extent on the degree of innovativeness, that is, it depends on the nature of the knowledge. Thus, the capacity of patents in supporting the capture and protection of value seems to be dependent on the value added by the new knowledge.

The managerial implication starts from the last point left off by the academic implication. It seems that, overall, the value of patents is related to the technical value of the invention. So, patenting of more ordinary inventions may not necessarily be fruitful due to the ease with which rivals can invent around innovator's patents. Patenting is justified not only because of the risks of loosing proprietary control of valuable innovations but also because the degree of protection might be higher when the degree of innovativeness is higher.

Although we conjecture that the distribution of R&D expenses might cause different patenting behaviours across industries, we could not formally test this. This might be one limitation of this research that deserves further investigation, especially because that distribution might not be officially detailed in firms' accounts and respondents might perceive differently what is meant by each activity, even if definitions are provided (as we did).

CHAPTER 8

CONCLUSIONS

8.1 INTRODUCTION

This chapter concludes this thesis, which is an investigation of the perceived importance and use of patents in UK manufacturing. The data analysed come from three different sources: interviews with personnel dealing with patenting issues; responses to a postal survey undertaken by the UK Office for National Statistics; and responses to a postal survey carried out by the researcher. The interviews served as the starting point of this research, providing information on patent-related issues that formed the foundation upon which a survey, with similar content, was designed and undertaken. The other survey, carried out by the government, is known as the Community Innovation Survey (CIS) and provided information about innovative activities of UK firms. The two surveys differ in scope; one (i.e., CIS) focuses on various aspects of innovation, paying little attention to patenting, and the other focuses mainly on firms' patenting behaviour.

The findings contribute to the understanding of what makes firms perceive patents as more or less important; how patents (if at all) interact with other appropriability mechanisms; and how firms act with respect to four basic questions - why patent?, where to patent?, what to patent?, and when to patent?. The results are summarised in the next section. In the third section, implications at different levels are drawn from the results. The fourth section addresses some of the limitations associated with this investigation. Finally, the last section raises issues that can be explored in future research.

8.2 SUMMARY OF FINDINGS

In reviewing the literature on patents some issues emerged as not yet explored or partly explored. We concentrated on several which were transformed into three general research questions:

i) To whom are patents important?

ii) Do patents complement or substitute for other appropriability mechanisms?

iii) How do firms produce their own patent portfolios?

Each research question was translated into an operational question and was tackled using a research technique accordingly. They are presented next along with the main findings.

8.2.1 *WHAT MAKES FIRMS PERCEIVE PATENTS MORE (OR LESS) IMPORTANT TO PROTECT THE RETURNS FROM INNOVATION?*

This question was answered by an econometric analysis of firms in UK manufacturing that responded to the questionnaire in the third round of the UK Community Innovation Survey. The analysis was based upon the ordered logit model framework, which consists of a non-linear regression technique that accounts for the qualitative and ordered nature of the response variable (i.e., the importance of patents).

Generally speaking, our findings are that i) the importance of patents varies across industrial sectors and by firm size, ii) patents are more important for firms with greater innovative capacity, iii) competition is to a certain extent conducive to a greater importance for patents, iv) innovation collaboration and government support may increase the importance of patents depending on the agents engaged in these activities, and v) the importance of patents is also dependent on firms' appropriation intent.

More specifically, our results suggest that the industrial sectors in the UK that value patents most to protect their innovations are: pharmaceuticals; chemicals; medical and precision instruments; machinery; and communication equipments. In turn, patents are least important to: printing and publishing; fabricated metals; food, beverage and tobacco; and textiles and clothing.

The results also indicate that larger firms are more likely to perceive patents as more important than are smaller firms. Firms with larger innovative effort place more value on patents than do less innovative firms. Firms operating in more competitive environments are more likely to perceive patents as of high importance compared to those operating in less competitive surroundings. Firms that establish innovation partnerships with universities are driven to perceive patents as more important than are firms not involved in that type of collaboration. However, joint-innovation projects with suppliers, clients or competitors do not make firms perceive patents as more important than those firms that do not take part in these partnerships. Support given by the government may increase the perceived importance of patents to smaller firms, but it is unlikely to do so to larger firms that may even perceive patents as less important. Last, the results suggest that firms that are more concerned about appropriating the returns of their innovation are more likely to put more emphasis on the importance of patents.

8.2.2 *HOW DO FIRMS' PERCEPTION OF THE IMPORTANCE OF OTHER APPROPRIABILITY MECHANISMS IMPACT ON THE DECISION TO PATENT AND ON THE LEVEL OF PATENTING?*

Just as the previous question, the answer to this question comes from responses to the Community Innovation Survey. Again, an econometric-based technique was employed. At this time, the regression analyses derive from zero-inflated negative binomial models. This framework accounts for the non-negative and integer nature of the dependent variable (i.e., number of patents applied for). Moreover, this technique allows for a large number of zeros in the dependent variable. Furthermore, the zeros are treated as coming from different decision-making processes (one where there is no invention available, and another where, even if available, the invention was chosen not to be patented).

Taken as a whole, the results suggest that the substitutability hypothesis should be refuted. In other words, patents seem to work as a complement, rather than a substitute, to other mechanisms employed to appropriate the results from innovation. The results point out that the more importance firms place on confidentiality agreements, secrecy, complexity of the design, trademarks, copyright, registration of design, or lead-time, the more likely they are to apply for a patent. However, given that a decision is made, a higher perceived importance of a mechanism does not necessarily mean that more patents are applied for, especially for confidentiality agreements and lead-time. But even in these cases, our findings do not show a negative and significant relationship that could support the idea that the mechanisms work as substitutes.

The results indicate that, in the cases of secrecy, copyright, trademarks, and complexity of the design, there seems to be an inverted-U relationship between the degree of importance of these mechanisms and the number of patents applied for. Thus, there seems to be a threshold after which the number of patents starts to decline. But, still, the degree of importance impacts positively on the number of patents (other things constant). For secrecy and copyright, firms that place most importance on one of these mechanisms still use patents more often than those firms that do not place value at all on those mechanisms. With respect to trademarks and complexity of the design of the innovation, firms that attach most importance to these mechanisms and firms that judge these mechanisms worthless apply equally for patents.

Our findings also show that not only the decision to patent but also the level of patenting are determined by the emphasis firms place on appropriation. Thus, according to our metrics, appropriation intent seems to be correlated to firms' patenting behaviour, and those more concerned about appropriation are those who apply most for patents (*ceteris paribus*).

We also find that changes in strategy have apparently made firms more prone to patenting. As we observed that the level of patenting seems to have more to do with firms' innovative capacity than with their strategic behaviour, this higher inclination to patent is likely to be because innovativeness is not concentrated only on technology-related issues; it spans the various functions of an organisation, including strategy. Thus, the increase in the number of patents is more likely to be a result of innovation contagion than of strategy *per se*.

8.2.3 *HOW DO FIRMS ACT WITH RESPECT TO FOUR BASIC QUESTIONS – WHY PATENT?; WHERE TO PATENT?; WHAT TO PATENT?; AND WHEN TO PATENT?*

Unlike previous questions, this set of questions is answered by the analyses of responses to a different survey. A new survey of UK R&D-based firms (derived from the UK *R&D Scoreboard 2001*) was designed and administered. But before designing the survey, a series of interviews with personnel in charge of patents within the pharmaceutical industry was run. The interviews were used as a foundation for the design of the survey instrument as well as a supplementary source of information to the responses of that questionnaire.

Overall, the results indicate that firms' patenting is motivated mainly by exclusionary purposes. The countries where applications are filed most are those where firms already operate or will operate in the near future. Product innovations are more likely to be patented than process innovations. Although sometimes a narrow scope can be more valuable than a broad scope, firms are in general keener to achieve a broader protection by either holding a broad patent with high inventing around costs or by securing a series of patents on variations of the invention or on its various aspects. This is apparently achieved by filing the first patent application (the priority application) early in the innovation process, that is, after one third of the time used to generate and market an innovation runs out. However, this is not the full story because, despite applying early in that process, follow-up applications can be filed.

An unexpected finding to emerge from the results was that patents might be as important to process innovations as they are to product innovations.

Our existing knowledge suggests that product innovations are patented more often than process innovations, and thus patents are thought to be more important to product innovations. Although we did not find the contrary with respect to the frequency with which each type of innovation is patented, in exploring the skewness in the distribution of the value of innovations we detected that the share of the most valuable patented product and process innovations do not statistically differ.

Our results also detected some different patenting behaviour between the industry where the final innovation comprises several patentable parts (complex industry) and the industry where the final innovation consist of relatively less patentable parts (discrete industry). Most notably, firms in the former industry perceive that a larger proportion of inventions, in comparison to firms in the latter industry, were not patented because of the risks of the patent not being valid or being invented around. This is consistent with another finding that indicates that firms in the complex industry rely more on narrow patents than firms in the discrete industry to protect their most valuable innovations. As a result, complex firms reported to seek patents with high inventing around costs more often than discrete firms do, though, according to our results, they do not seem to achieve that purpose. One could argue that such differences are explained by the very nature of the final innovation (i.e., the number of patentable parts of the final innovation). As in the complex industry overlapping patents ('patent thickets') are expected to happen more often, it might be easier for patent disputes to happen, and more difficult to hold a broad patent without infringing someone else's patents. However, we did not find that the costs of patent disputes affect one industry more than the other. Neither did we find that the risks of an induced deal due to overlapping patents differ between discrete and complex industries. We conjecture therefore that such differences rest with the distribution of R&D expenses in either industry. Contrary to firms in the discrete industry, firms in the complex industry spend more on development activities than on applied research. Thus, the innovations of the former industry are more likely to be of lower technological content. As a consequence, they might be, if patented, easier to circumvent or invalidated, and also of narrower scope than patents generated from innovations reliant on applied research.

8.3 IMPLICATIONS OF THE RESEARCH

8.3.1 *ACADEMIC IMPLICATIONS*

One immediate academic implication of this research is that it reinforces the idea that the usefulness of patent statistics as an indicator of inventive performance is limited. Although the most innovative firms were found to place more value on patents, firms' other attributes (e.g., size, industrial sector) should be taken into account for a proper comparison.

This research also shows that although decisions as to when firms apply (or not) for patents may be taken strategically, the number of patents seems to be governed mainly by firms' innovative capacity and their interest in stopping others from copying. Thus, the noisiness in the patents-R&D relationship due to the manifold use of patents seems to be only marginal and have only limited impact on the estimation of propensities to patent when the number of patents is the response variable. Nevertheless, there remains interference of other factors difficult to control such as the efficiency of R&D.

Regarding valuation purposes our results suggest that patent statistics should also be used and interpreted cautiously. For example, the rationale that in general broader patents are more valuable than narrow patents might be correct. But a broader patent scope also increases the risks of a patent being challenged. Moreover, national patent systems may not favour broader patents (in case of a cross-country comparison). Thus, patent scope might not be unambiguous and should be dealt with care. Our results indicate that, in fact, narrow patents can be valuable, even if to a lesser extent than broad ones.

Our findings also point that another indicator that deserves attention is the size of the patent family. We observed that the driving force guiding patenting abroad is the economic one. So, it is likely that the larger the size of the patent family the more valuable a patent is. But this is more reasonable to accept when the indicator used is granted patents rather than patent applications due to practicalities of supra-national routes that allow delays in the decisions about which countries the application will progress. It is also fair to say that patents are granted at different points in time, according to the patent systems' work load. So, it might be that patent grants in the triad (i.e., EU, US, and Japan) might suffice.

Again, for patent valuation purposes, the payment of renewal fees may be a good *proxy* for the most valuable patents. However, the extent to which renewal fees are paid may not correspond necessarily with whether a patent will be enforced if infringed; there seems to exist an optimum patent life after which the costs of defending a patent in court are not (strategically) justified. Inter-industry differences in how long firms are interested in enforcing intellectual property rights could be observed.

One theoretical implication is that the results point in an opposite direction to one theory in the economics of the patent system that assumes that follow-on work is not patentable. We observed that firms may apply for follow-ups and also that patents are taken out by firms that concentrate their R&D expenses on development activities. Follow-ups also mean that firms may never be sure about the extent their patents are valid, and this supports the 'probabilistic patents' theory. In following up, firms attempt to stack the odds in their favour if the priority patent is challenged by someone else because they will have other related patents either covering other particularities of the original invention or providing more evidence of the originality of the invention.

Our research also reiterates how difficult it is to coordinate patent breadth and length to correct for market imperfections on the basis of a 'one size fits all system'. Both dimensions were found relevant to patent holders. The overall picture is that other benefits brought by patents are dependent to a large extent on the degree of excludability achieved (i.e., the strength of monopoly power). Thus, the strategic role they play is mainly in demarcating the contours of technological boundaries, allowing firms to have freedom of operation within a particular space and controlling who can step into that domain. Contrary to what a few economic models assume there is, according to our research, little space (and perhaps time) for innovators to produce non-trustful signals. Innovators concentrate on managing the disclosure of valuable information instead. However, assuming that the knowledge that is patented is the same that is kept secret does not take into account the various dimensions of knowledge. Thus, under that assumption, different methods cannot be used simultaneously, but this does not fit the facts (at least at firm level). Appropriability conditions seem to be enhanced when patents and other appropriation mechanisms are used concurrently. Thus, in examining appropriability conditions the degree that the knowledge can be appropriated by various, or at least a few, methods should be incorporated in economic models.

A final implication for theory is that the effectiveness of patents as an isolating mechanism depends to a certain degree on the type of knowledge that is translated into inventions. Our results indicate that patents are more effective when encompassing knowledge created under riskier and more uncertain conditions, that is, knowledge that is more likely to be valuable and sought to be captured by rival firms.

8.3.2 *PUBLIC POLICY IMPLICATIONS*

Our findings revealed that smaller firms pay less attention to patents than do larger firms (other things equal). This however should not alarm policy makers because the most innovative firms, even if of reduced size, place more importance on patents than their less innovative counterparts. This means that small high-tech firms do not need any special policy to be stimulated to patent. The same cannot be said to other smaller and less innovative firms. Perhaps they need more stimuli to use patents to the same extent that their larger counterparts. In general, the literature (e.g., Kingston 2001) reports that some aspects of the post-patenting phase should be further elaborated or improved such as the renewal scheme, out-licensing conditions, and especially litigation. These are claimed to benefit a broader spectrum of firms, though the effects are unlikely to be the same across industrial sectors.

Our analyses also indicate that government support may affect the importance firms place on patents, depending on their size. If the support is given to larger firms, patents become less important (compared to those who do not receive any support). If smaller firms are the ones who receive government support, patents are perceived of higher importance. This might be desirable if this policy is not weakening the competitiveness of those firms most likely to compete abroad (i.e., larger firms) because as our results indicate for those whose major market is the international one, patents are very important.

It was possible to discriminate, from a sample of the largest R&D spenders in the UK, between firms that operate in industries where the final innovation is a result of several patentable parts (complex) and firms that operate in industries where the final innovation consists of relatively few patentable parts (discrete). Complex firms perceive it to be more difficult to hold patents that are difficult to circumvent than discrete firms perceive. This indicates a more fragile position of complex firms, compared to discrete ones, in competing on the basis of controlling intellectual property rights. Complex firms also reported to concentrate mainly on development/ design activities while discrete firms concentrated on applied research. This may explain why it is more difficult to secure stronger patents in the complex industry than in the discrete industry. Perhaps this suggests to policy makers that it is not only the total R&D costs that matter but also what these costs are used for (i.e., the distribution of R&D outlays).

Comparing our UK findings and the findings of another survey administered in the US and Japan (Cohen et al. 2002), one can observe that the way in which the UK patent system is used presents some similarities with the way the US and the Japanese systems are used. All of them are exploited mainly for exclusion of third parties. While in Japan patents are largely used for negotiations as well, in the UK and in the US this use is more limited. In the US the use of patents in negotiations is common within the complex industry. In the UK that use is limited in either industry. Despite the benefits of those negotiations of sharing intellectual property rights they have costs (e.g., firms have less autonomy) that may outweigh the benefits. With the data available it is not possible to assess whether the UK patent system is less socially desirable than the US and the Japanese patent systems. But it seems that the findings are signalling that attention should be paid to increasing the capacity of the UK patent system to promote knowledge sharing. This is perhaps reinforced by the evidence that the use of patent information for technical problem-solving is not amongst the most important reasons why firms seek patent information for; they concentrate mainly on the use of patents for competitive analysis. As the former type of information is expected to help in the diffusion of knowledge, the UK patent system may not be properly playing one of its roles, i.e. promoting R&D spillovers.

Although we found that the use of patents as bargaining chips is not widespread in the UK, this does not mean that knowledge sharing as a whole is a rare event. Moreover, despite the results indicating that to a large extent patents do not work as a catalyst to promote negotiations, we detected that under certain circumstances it can be the other way round (i.e., partnerships fostering patenting). This was the particular case of joint-innovation projects between universities and firms. Firms involved in this type of collaboration are more likely to judge patents highly important compared to their counterparts not involved. This brings up another area where government should pay careful attention due to the difficulty in detecting the extent that public resources should become private.

8.3.3 *Managerial Implications*

Several managerial implications can be drawn from this research. One of them is that patents should not be thought of in isolation from other mechanisms of appropriability. As no method of appropriation is perfect, appropriability conditions are likely to be enhanced if firms know which mechanisms should be used and when. Our results suggest that firms employ these mechanisms collectively in order to strengthen the extent that they can appropriate the returns from their innovative effort, although this does not mean that all of them have to, or can, be used. The effort devoted to each of the mechanisms has to be in line with the degree of appropriability sought and with the degree of appropriability that is feasible (depending on the regimes of appropriability peculiar to each industry). What seems clear from our results is that patents are paramount, and even more effective, for the innovative activity of higher value added.

In choosing to patent an invention innovators should master the patenting process. If not fully aware of the legislation, support should be sought because, as we observed, the strength of a patent lies in its capacity to hinder competition, and this is achieved by, amongst other things, the decisions taken during the patenting process; decisions as to why, what, when and where to patent. Moreover, firms do not have to enforce their patents for the full patent life, even if a patent is infringed. At some point in the patent term it might be better to devote time and effort to the creation of new value than to the forestalling of the dissipation of the existing value.

We also observed that the ability of firms in using patents to signal to the market (either in the form of an application or by stopping paying renewal fees) with the purpose of influencing competitors is quite limited. Although we do not know the costs of doing that (and we do not claim this is costless), perhaps the returns from patents could be higher, even if not detected, than the returns brought mainly by delimitating the boundaries of the technological space, especially because firms reported to use patent information mainly as a tool to support competitive analysis.

One final comment regards the simplistic view that holding a single patent will generate adequate excludability. Although a strategic patent may be rather effective it is mainly by managing a whole portfolio of patents that firms will generate the full benefits of patents and limit the operations of (potential) competitors. In particular, if the decisions taken along the patenting process match the business purpose. One of our interviewees mentioned that working with patents is the same as playing a 3D-chess. It is complex and players cannot neglect the strategic character of the 'game' that demands both defensive and aggressive movements.

8.4 Limitations of the Study

This research, as any other, has its limitations and one of them is rather obvious: its territorial coverage. Although the results are valid for firms in UK manufacturing, it is difficult to extrapolate all of our findings across-borders. In fact, addressing a comparison between our results and an earlier study for the US and Japan, we noticed different appropriability conditions. This might reflect on the extent to which our conclusions can be generalised.

Another limitation is the level of analysis which is mainly at the (aggregate) firm level. While this gives a better visibility of the overall picture, the results do not match all cases, and perhaps interesting exceptions have been missed. Furthermore, analysis at the innovation level may reveal important aspects of knowledge creation and decisions about its appropriability that our level of analysis was not able to portray.

Inter-temporal changes are likely to be observed in some aspects of patenting activity (e.g., importance of patents). As our analyses derive from cross-sectional data, such results are not observed.

Other rather important limitations regard the interaction of patents and other mechanisms of appropriability. Our analyses do not take into account the variability in their importance at the various stages of the innovation process. This could further reveal whether they, in fact, work as complements or substitutes.

8.5 FUTURE INVESTIGATION

Starting from the point at which we finished the last section, this research and earlier research have focused on the interaction between patents and other appropriability mechanisms but it has not taken into account when this interaction happens or when it is stronger (or weaker). This is a fertile area of research that should be explored.

One question that should be answered is whether appropriation strategies do indeed exist, or are consciously formulated and deployed.

Although the interaction of appropriability mechanisms may suggest so, the way patent information is used for may suggest the contrary. Therefore, more sophisticated analytical approaches from the strategic management literature could be used in pursuing an answer to that question.

Other questions also remain unanswered and merit further investigation. For example, is the role of patents as a channel of information flow really limited in the UK? Why do firms in the UK apparently use patents in negotiations less often than firms in the US and Japan?

Further research could examine the effects of market structure on decisions taken to produce patent portfolios. Or could explore the conditions within which follow-up patent applications are pursued.

And finally, another area of research that deserves a special study is that regarding why university partnerships make firms perceive patents as more important.

These are all promising areas of research which will help us in expanding the boundaries of our current knowledge on the role patents play in strengthening firms' competitiveness and in welfare creation. Although we recognise the operational difficulties in approaching those issues we believe that enterprise is worth it because in the end "[w]e should not be cursing the darkness, but rather, we should keep on lighting candles" (Griliches 1990:1703).

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APPENDICES

Appendix 1
The Community Innovation Survey

The 'Community Innovation Survey' (CIS) is a pan-European effort to gather information on the extent and level of technological innovation activity at the firm-level[196]. Information on firms' innovative activities was collected by means of a survey instrument designed by all EU Member States. As a result, indicators of innovative output and qualitative information on several innovation related issues (e.g., industry, turnover, employment, R&D expenses, sources of information, patenting) are produced.

The data set used in this thesis relates only to the UK responses to the third round of the 'Community Innovation Survey' (CIS 3). The CIS 3 was administered in 2001 in the UK by the Office for National Statistics (ONS) on behalf of the Department of Trade and Industry (DTI). The survey encompasses innovative activities during the period 1998-2000, but this is no time series. This period was used just as a reference for several questions. Therefore, we shall be working with a cross-section[197] of firms.

In the UK it was a voluntary survey addressed to firms with more than 10 employees in both manufacturing and services industries, that is, those classified in the sections C-K of the UK Standard Industrial Classification of

[196] In fact, the unit of analysis is the enterprise, which is defined as the smallest combination of legal units with a certain degree of autonomy within an enterprise group (a number of enterprises under common ownership).

[197] A panel of at most 800 firms which responded to both CIS 2 and CIS 3 could be used but we could not see any benefit in reducing our sample size to work with a short time span without any relevant event for our study.

Economic Activities (UK SIC92). For the purposes of this thesis we will focus only on the manufacturing industry (section D).

Access to individual returns was kindly provided by the DTI but in order to preserve confidentiality no identification of the respondents was disclosed. The achieved sample was 8,172 enterprises, drawn from a sample frame of 19,602. This sample frame derives from the population of 126,775 records of the Inter-Departmental Business Register (IDBR). Our sample, however, by focusing on manufacturing consists of, at most, 3440 firms, which is about 42% of the total sample and 7.5% of the whole population of UK manufacturing firms registered in the IDBR[198].

[198] The real figures are smaller since we only use valid responses in our analyses.

Appendix 2
Interview Guide

1. Could you briefly describe your company's profile?

- Ownership
- Market
- Technology

In case of being a parent company:

1.a. Does your company have R&D units abroad?

1.b. If so, Where do the overseas R&D units first apply for a patent?

- Country where subsidiary operates?
- Parent company home country?

In case of being a subsidiary:

1.c. Does your company first apply for a patent in the UK or in its parent company home country?

In case of being neither a parent company nor a subsidiary: Next question

1.d. Has your company taken out patents in a country non-signatory of the Paris Convention?

1.e. If so, How has your company avoided forfeiting a patent due to public disclosure?

2. What determines the selection of the country where your company applies for a patent?

- Competitive Environment
- Type of patents
- Potential market
- Legal Framework

2.a. To what extent does your company make use of the Patent Cooperation Treaty?

2.b. What are the advantages of the PCT?

2.c. And the disadvantages?

2.d. Does you company apply for a patent to the European Patent Office?

2.e. Is there any time that your company applies for a patent just to the United Kingdom Patent Office as opposed to the European Patent Office?

2.f. If so, When?

2.g. If not, Why?

2.h. When is it interesting to delay the substantive examination of a patent application?

2.i. And when is it interesting to have a patent granted sooner?

2.j. In the UK the pharmaceutical industry is regulated by a price scheme, does it has any impact on the way your company applies for a patent?

2.k. Does your company file patent applications in countries where it does not operate?

2.l. If so, What are the reasons to do that?

3. What categories of invention does your company patent most frequently?

- Process
- New use
- Product (Which one? - chemical entity, pharmaceutical composition, ...)

3.a. What category of patented invention gives more protection against competitors?

3.b. Why?

3.c. What determines a higher or a lower protection obtained in a patent?

- Nature of invention
- Decisions during development of invention
- Technology path
- Action taken to enforce patent rights

3.d. How can one identify whether a patent application does seek a strong protection?

- Number of claims
- Number of citations
- Number of examples

4. How does your company distinguish between what is and what is not worth patenting?

4.a. To what extent does your company analyse the patentability of inventions that are not within its core business?

4.b. What about those inventions that emerge as a result of non-routine activities?

5. What issues should be analysed before deciding that an invention will be publicly disclosed as opposed to keeping it secret?

5.a. To what extent is it necessary to disclose the real invention?

5.b. Does your company think on the reasons for disclosing information in each patent application?

5.c. Does your company make use of both trade secrets and secrecy?

5.d. When does your company use trade secrets?

5.e. When does your company use secrecy?

6. When does your company start to realise what is going to be claimed in a patent application?

6.a. Could you describe your company's typical route of drug discovery?

6.b. At what stage of that route does your company decide that a patent application must be filed? (explorat'; target identificat'; screening; lead comp'd; scale up)

6.c. How much of the total R&D budget is still available after a patent application is filed?

6.d. Does your company establish deadlines for a patent application to be filed?

6.e. How does it impact on the protection obtained?

6.f. Do softwares to model molecules impact on the timing of applying for a patent?

6.g. What about the degree of protection sought in a patent application?

6.h. Can you file other applications covering slightly different variations of an invention before the first one is published?

6.i. When do you do that: after or before the first year of the priority date?

6.j. Why do you do that?

6.k. Can you file several applications at the same time covering variations of an invention?

6.l. What is the advantage of doing that?

7. To what extent does your company aim at claiming not only an invention itself (underclaiming) but also its variations (overclaiming)?

7.a. What are the benefits of doing so?

7.b. And the risks?

7.c. What determines such overclaiming (or underclaiming)?

8. To what extent do your company's inventors make additional experimentation to define the boundaries of an invention?

8.a. Even when the invention is not crucial to your company's core business?

8.b. Does your company come across new inventions when performing further experimentation?

8.c. What kind of unexpected results may change the patenting objective?

8.d. Is that additional experimentation likely to extend a patent protection?

8.e. If so, in which way?

8.f. If not, why is it performed?

8.g. How much effort should be put in this phase?

9. How does your company use the time between a first patent application and its publication?

9.a. Does your company improve the primary invention?

9.b. If so, How do the outcomes of that additional work benefit your company?

9.c. Does your company search for prior art?

9.d. If so, In this case is the use of the Patent Cooperation Treaty an advantage?

9.e. How can either improvements on the primary invention or search for prior art affect the previous patent application?

9.f. Does your company abandon the former application or continues with it?

9.g. How similar is an invention claimed in a patent application to the one that in fact is launched on the market?

10. How effective are patents as a mean of gaining competitive advantage?

10.a. To what extent can patents block competitors' movement?

10.b. What actions can be taken to more effectively block competitors' movement?

10.c. How easy is it to invent around a patent?

10.d. What makes it easier or more difficult?

10.e. Does the ease of duplicating the function of the invention affect your company's decisions of whether or not apply for a patent?

10.f. When is it necessary to invent around a patent?

10.g. Does your company use patent as an indicator of inventive performance of your researchers?

10.h. Are patents used as part of incentive structures for your company's research workers?

10.i. Does your company use its competitors' patents to extract information from them?

10.j. If so, What kind of information is sought?

11. What determines the value of a patent?

- Possible users
- Competitors action
- Degree of protection
- Countries where granted
- Technological impact

11.a. To what extent are your company's patents individually significant?

11.b. How does your company detect its patents technological impact?

11.c. How can your company detect other companies' most valuable patents?

11.d. To what extent is the degree of protection conferred by a patent related to its technological impact?

11.e. How do both underclaimed and overclaimed patents add value to your company?

11.f. To what extent is the technological impact of a patent related to the success of marketing an invention?

12. What does your company take into account to decide to stop paying renewal fees?

12.a. Have those patents lost their value?

12.b. If so, What is likely to have happened to make those patents devalue?

12.c. If not, Why has your company decided to stop paying their fees?

13. What are the advantages of having a patent portfolio?

13.a. Has your company licensed out technology protected by patents?

13.b. If not, Do you foresee any possibility of licensing out in the future?

13.c. Has your company used patents in cross-license agreements?

13.d. If not, Would your company take the opportunity of that if it has the choice?

13.e. To what extent do patents likely to be used to license out technology differ from those likely to be used in cross-license agreements?

13.f. How can your company's patent portfolio be used to build up a relationship with its customers?

14. What are the weaknesses of patent protection?

- Costly to maintain
- Costly to defend
- Does not prevent imitation
- Too much disclosure
- If challenged, it is difficult to defend

15. What enables your company to more effectively appropriate returns from R&D?

- To exploit lead time
- To learn quicker than competitors
- To use sales and services capabilities
- To keep secret
- To have strong patent protection

15.a Do patents and those (or that) other mechanism(s) have synergy?

15.b. How do they complement each other?

16. What action would your company take if another company infringes its patents?

16.a Does that action vary according to the patent infringed?

16.b. What can affect such action?

17. Could you describe how patenting activities are organised within your company?

17.a. Does your company have a formal unit to handle just intellectual property issues?

17.b. What are the main tasks of those who deal with patent issues?

- Search for prior art
- Prepare patent applications

17.c. Does your company have an external patent agent (or attorney) or does it apply for a patent by itself?

17.d Why (or not) are they necessary?

17.e. How do your company's inventors participate throughout the patenting process?

Appendix 3
Correlation Matrix of Coefficients of Models (3) and (4)

Model (3)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
(1) R&D intensity	1.0000								
(2) Sales	0.4149	1.0000							
(3) Novel Prod.	-0.0151	-0.0877	1.0000						
(4) Gov. Support	-0.1327	-0.0928	-0.1039	1.0000					
(5) Univ. Partnership	-0.1921	-0.1062	-0.0960	-0.1757	1.0000				
(6) Local Mkt.	0.1660	0.0835	0.0461	-0.0305	0.0031	1.0000			
(7) Regional Mkt.	-0.0013	-0.1124	0.0875	-0.0187	-0.0458	0.1342	1.0000		
(8) International Mkt.	-0.0847	-0.1030	-0.1647	0.0270	-0.1039	0.1447	0.1924	1.0000	
(9) SAI index	-0.1788	-0.1131	-0.2425	0.0489	0.1273	0.0557	-0.0536	0.1492	1.0000

Model (4)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
(1) % Sci./ Eng. Staff	1.0000								
(2) Sales	0.0966	1.0000							
(3) Novel Prod.	-0.0986	-0.0763	1.0000						
(4) Gov. Support	0.0694	0.0057	-0.0760	1.0000					
(5) Univ. Partnership	-0.1371	-0.1493	-0.1110	-0.1989	1.0000				
(6) Local Mkt.	0.0545	0.0758	-0.0423	0.0455	-0.0216	1.0000			
(7) Regional Mkt.	0.0192	0.0700	0.0086	-0.1262	0.0176	0.0977	1.0000		
(8) International Mkt.	-0.1668	-0.0790	-0.0975	0.0317	-0.0253	0.1571	0.1899	1.0000	
(9) SAI index	-0.1387	-0.0962	-0.1604	-0.0897	-0.0046	0.0061	0.0900	0.0438	1.0000

Appendix 4
Industrial Sector Estimates of Ordered Logit Models from Table 5[a,b]

Industry	(1)	(2)	(3)	(4)
Basic Metals	0.556	1.240**	4.803***	3.998***
	(1.021)	(0.503)	(1.289)	(0.772)
Chemicals, except drugs	0.852	1.780***	6.350***	5.450***
	(0.811)	(0.418)	(1.316)	(0.743)
Communication equip.	1.026	1.688***	6.145***	4.968***
	(0.822)	(0.410)	(1.272)	(0.745)
Electrical equip.	0.904	1.720***	5.696***	4.776***
	(0.792)	(0.380)	(1.243)	(0.721)
Fabricated metal	1.349	1.530***	2.451**	2.213***
	(0.835)	(0.381)	(1.204)	(0.755)
Food, beverages and tobacco	-0.390	0.390	2.689**	2.437***
	(0.763)	(0.401)	(1.151)	(0.732)
Glass, clay and ceramics	0.584	1.504***	4.425***	3.834***
	(0.981)	(0.451)	(1.352)	(0.774)
Machinery, except office	1.495*	1.994***	6.344***	5.125***
	(0.794)	(0.378)	(1.263)	(0.726)
Medical and precision instr.	1.243	1.841***	6.480***	5.138***
	(0.818)	(0.393)	(1.275)	(0.733)
Motor vehicles	0.841	1.750***	5.439***	4.796***
	(0.834)	(0.377)	(1.263)	(0.723)
Office and computing equip.	0.949	1.027*	5.691***	4.263***
	(1.052)	(0.541)	(1.354)	(0.787)
Other manufacturing	0.940	1.502***	4.634***	3.554***
	(0.786)	(0.368)	(1.184)	(0.710)
Other transport equip.	0.395	0.671	4.089***	3.198***
	(0.958)	(0.439)	(1.328)	(0.778)
Pharmaceuticals	1.522	1.749***	7.578***	6.026***
	(0.997)	(0.647)	(1.380)	(0.835)
Refined petroleum products	0.136	1.206	4.030**	4.487***
	(1.207)	(0.982)	(1.892)	(0.980)
Rubber and plastic products	1.362*	1.848***	5.695***	4.682***
	(0.820)	(0.404)	(1.236)	(0.738)
Textiles and clothing	0.826	0.964**	3.718***	2.514***
	(0.901)	(0.400)	(1.179)	(0.753)
Wood and paper	0.646	1.533***	4.164***	3.805***
	(0.849)	(0.400)	(1.195)	(0.737)

[a] The comparison industry is Printing and Publishing.
[b] * significant at 10%; ** significant at 5%; *** significant at 1%.

Appendix 5
Profile of the 'Complex' and 'Discrete' Industries

(i) **Discrete industry** - sectors with UK SIC 92 codes less than 29 (e.g., food, beverages, and tobacco, chemicals, pharmaceuticals, metals);

(ii) **Complex industry** - sectors with UK SIC 92 codes 29 or above (e.g., machinery, communication equipments, medical, precision and optical instruments, office and computing equipments).

Industry	Variable	N	mean	sd	min	max
Discrete	% Sci./Eng. Staff	1288	3.814	9.375	0	100
	Sales (£'000s)	1288	23096	136687	7	3447748
	# Patents	1288	1.06	10.58	0	300
Complex	% Sci./Eng. Staff	1126	6.551	12.419	0	100
	Sales (£'000s)	1126	16321	51406	13	1170824
	# Patents	1126	1.53	7.77	0	100

	Discrete (%)	Complex (%)	N (row total=100%)
Introduced a product innovation			
No	54.05	45.95	2063
Yes	49.29	50.71	351
Total	53.36	46.64	2414
Market			
Local	70.21	29.79	329
Regional	70.75	29.25	318
National	50.98	49.02	1330
International	35.24	64.76	437
Total	53.36	46.64	2414
Government support			
No	54.80	45.20	2106
Yes	43.51	56.49	308
Total	53.36	46.64	2414
University partnership			
No	53.85	46.15	2258
Yes	46.15	53.85	156
Total	53.36	46.64	2414

Appendix 6
Exploratory Models of the Determinants of Patent Applications[a,b]

Covariates	(A)		(B)		(C)		(D)	
	Decision	Count	Decision	Count	Decision	Count	Decision	Count
R&D intensity (Log)	-0.216	0.205***			-0.054	0.370***		
	(0.194)	(0.074)			(0.127)	(0.075)		
% Sci./Eng. Staff			-0.008	0.020*			-0.006	0.025**
			(0.014)	(0.012)			(0.010)	(0.010)
Sales (Log)	0.017	0.702***	-0.292**	0.473***	-0.028	0.582***	-0.335***	0.375***
	(0.353)	(0.107)	(0.127)	(0.092)	(0.156)	(0.074)	(0.122)	(0.065)
Novel Product	-1.090	0.331	-1.783***	0.671***	-0.756	0.304	-2.191***	0.394
	(0.828)	(0.248)	(0.396)	(0.243)	(0.495)	(0.263)	(0.645)	(0.320)
Local market[c]	0.523	-0.534	2.147***	0.594	-10.271	-2.396***	1.534*	-0.519
	(5.730)	(3.603)	(0.679)	(0.777)	(6.779)	(0.848)	(0.916)	(0.712)
Regional market[c]	2.189	1.195	1.094	-0.574	-18.31***	-1.449**	-0.426	-2.136***
	(1.880)	(1.208)	(0.894)	(0.866)	(1.273)	(0.704)	(0.814)	(0.496)
Intl. market[c]	0.198	0.428*	-0.321	0.700***	0.423	0.724***	-0.208	0.935***
	(0.802)	(0.234)	(0.338)	(0.247)	(0.547)	(0.246)	(0.360)	(0.261)
Gov. Support	0.326	-0.347	-0.521	-0.379	0.617	-0.187	-0.126	-0.146
	(3.088)	(0.592)	(0.489)	(0.275)	(0.552)	(0.314)	(0.666)	(0.326)
Univ. Partners.	-2.626	0.314	-2.562***	0.201	-22.70***	0.281	-6.431	0.204
	(2.310)	(0.329)	(0.971)	(0.304)	(7.916)	(0.317)	(69.954)	(0.360)
Complex					-1.046*	-0.175	-0.727**	-0.241
					(0.628)	(0.286)	(0.365)	(0.344)
Constant	0.358	-2.913***	5.595***	-2.447***	0.112	-2.917***	4.444***	-3.060***
	(3.380)	(0.957)	(1.326)	(0.877)	(1.727)	(0.806)	(0.895)	(0.819)
Industry Dummies	Yes		Yes		No		No	
N	484		2414		484		2414	
Non-zero obs.	175		316		175		316	
Ln α	0.598		1.159***		0.929***		1.464***	
Log-Likelihood	-742.35		-1509.61		-771.31		-1559.08	
Model Chi-square	418.08***		280.46***		165.42***		160.17***	
Pseudo R^2	0.144		0.172		0.111		0.145	
BIC	-1167.41		-15355.13		-1319.68		-15521.02	
AIC	3.295		1.296		3.274		1.309	
Vuong test	3.33***		5.84***		2.46***		4.77***	
LR test	1156.43***		2522.70***		1580.43***		3017.53***	

[a] Robust standard errors in parentheses.
[b] * significant at 10%; ** significant at 5%; *** significant at 1%.
[c] The reference market is the national market.

TEXT BOUND INTO

THE SPINE

Appendix 7
The Patent Survey Instrument

SURVEY

ON

PATENT ACTIVITY

MARKETING AND STRATEGIC MANAGEMENT GROUP

All replies will be treated as strictly confidential

Winter
2002/ 2003

he objective of this study is to examine in which ways manufacturing firms in the UK use the patent stem, and the extent that this system helps those firms to recoup their investments in innovative tivities. It is being carried out within the Marketing and Strategic Management Group of the Warwick usiness School, University of Warwick. All information provided will be held in the strictest confidence. e <u>will neither publish, release, nor disclose any information on, or identifiable with, individual ompanies or business units</u>.

IRECTIONS

he survey is designed to be responded to by the person most aware of the patenting activities within your ompany (e.g. patent managers/ administrators/ directors, intellectual property rights managers/ directors, R&D anagers/ directors). In cases of subsidiaries of foreign companies, the questionnaire is to be responded to by the erson most aware of the decision-making process regarding patenting activities in the UK.

he questionnaire consists mostly of closed questions, that is, questions to be answered either by ticking (e.g. ☑) or rcling (e.g. 1 2 ❸ 4 5) the appropriate option. Note that for some questions which refer to proportion/ rcentage, the sum does not have to round to 100% since options may work simultaneously. The remainder of the estionnaire consists of open questions, which we expect you to answer **based on your best estimate**. You do OT need to search your files or consult with colleagues to provide more detailed answers. In order to avoid isunderstandings, please use **BLOCK CAPITALS** whenever necessary. Please answer to the best of your ability sed on your understanding of your company's business and its activities. If any question **does not apply** to your mpany, please write **N/A** beside its index (e.g. A1, a, i, II). If you **do not know the answer**, please leave the estion/ item **blank**.

el free to add comments to clarify your answers, to add supplementary answer categories, or to make other mments on the questions.

OUR CO-OPERATION IS OF GREAT VALUE.

hen finished, please return the completed questionnaire in the addressed postage paid envelope.

we can assist you in any way, or if you have any queries or comments, please do not hesitate to contact the earch officer in charge of this study:

R HENRIQUE BARROS
rketing and Strategic Management Group
rwick Business School
versity of Warwick
ventry
4 7AL
024 7652 2087
ail: H.M.Barros@warwick.ac.uk

Section A
About Your Company

1 - Is this business unit: (Tick one box)

The Head Office ☐ (go to **A4**)

A Subsidiary ☐ (go to **A2**)

2 - Where is your company's Corporate Head ffice located?

UK ☐ (go to **A4**)

Abroad ☐ (go to **A3**)

3 - Is your company's business unit(s) operating in e UK responsible for its own patenting?

Yes ☐

No ☐

A4 - In order of sales volume, please indicate your 5 major country markets (including the UK, if applicable):

	Country	Approximate % Total Sales
1st	______	______%
2nd	______	______%
3rd	______	______%
4th	______	______%
5th	______	______%

5 - What option below best describes the industry to which your R&D activities **MOST** apply? (circle number)

Food Products, Beverages and Tobacco
Textiles and textile products
Leather and leather products
Wood and wood products
Pulp and paper
Publishing, printing and reproduction of recorded media
Chemicals (excl. pharmaceuticals), chemical products, and man-made fibers
Medical instruments
Pharmaceuticals
Coke, refined petroleum products and nuclear fuel
Rubber and plastic products
Other non-metallic mineral products

13. Basic metals and fabricated metal artefacts (excl. machinery and equipment)
14. Transport vehicles and equipments
15. Radio, television and applied apparatus
16. Telecommunication equipments and artefacts
17. Precision and optical instruments, watches and clocks
18. IT hardware
19. Office machinery
20. Electrical machinery and equipment
21. Electronic machinery and equipment
22. Other machinery and equipment
23. Other (please specify)______________________

Throughout this questionnaire this is going to be referred to as your <u>FOCUS</u> industry.

- Could you please provide some examples of the output of your R&D activities? (Use BLOCK CAPITALS)

____

____

- Considering your FOCUS industry, please give the approximate figures for your operations in the UK:

Market share ______%

b. Proportion of total sales **a.** ______________%

c. Share of total sales based upon inventions protected by patents belonging to you **a.**______________%

For the purposes of this study product inventions are both i) improved products whose TECHNOLOGICAL performances have been significantly enhanced and ii) new products (either to the company or to the industry) whose TECHNOLOGICAL characteristics make them differ completely from the existing or previously produced ones. Process inventions are both new and significantly improved production or delivery methods. Innovations are inventions that have useful and commercially viable applications.

8 - In your FOCUS ndustry, for what proportion f your PRODUCT novations has each of the llowing been a key element increasing your returns om those innovations? ircle for each option)	Less than 10%	10-30	31-50	51-70	71-90	More than 90%
Exercising secrecy	1	2	3	4	5	6
Taking out patents	1	2	3	4	5	6
Securing other IPRs	1	2	3	4	5	6
Being first to market	1	2	3	4	5	6
Being able to secure other mplementary technological mponents	1	2	3	4	5	6
Providing complementary les/ service	1	2	3	4	5	6
Controlling specialised nufacturing facilities/ pabilities	1	2	3	4	5	6
Creating costs for clients itching to another mpany	1	2	3	4	5	6

- For your PRODUCT innovations which patents y a key role, what share corresponds to your most LUABLE innovations?

a. __________%

A10 - In your FOCUS industry, for what proportion of your PROCESS innovations has each of the following been a key element in increasing your returns from those innovations? (circle for each option)	Less than 10%	10-30	31-50	51-70	71-90	More than 90%
a. Exercising secrecy	1	2	3	4	5	6
b. Taking out patents	1	2	3	4	5	6
c. Securing other IPRs	1	2	3	4	5	6
d. Being first to market	1	2	3	4	5	6
e. Being able to secure other complementary technological components	1	2	3	4	5	6
f. Providing complementary sales/ service	1	2	3	4	5	6
g. Controlling specialised manufacturing facilities/ capabilities	1	2	3	4	5	6
h. Creating costs for clients switching to another company	1	2	3	4	5	6

A11 - For your PROCESS innovations which patents play a key role, what share corresponds to your most VALUABLE innovations?

a. __________%

Section B
About Your Internal Patent Policy

- Did you have any annual numerical target for ent filings last year?

es ☐ *How many?* __________

No ☐

B2 - Please indicate your (UK and abroad) number of INTERNAL patent attorneys/ agents last calendar year:

a. __________

B3 - What percentage of the above were located in the UK?

a. __________%

4 - Which one of the following best describes your titude with respect to the patenting of your product nd process inventions?

	Product	Process
Do not patent anything (i.e. ep things secret)	☐	☐
Patent inventions that may e used or marketed by your mpany	☐	☐
Patent inventions that may e used or marketed either by ur company or by its main mpetitors	☐	☐
Patent nearly everything that patentable	☐	☐

B5 - What action are you more likely to take when you come across a patent (or a series of patents) which it is very difficult/ costly to invent around?

	Very Unlikely	⟷				Very Likely
a. Ignore or infringe	1	2	3	4	5	6
b. Challenge the corresponding patent(s) in court	1	2	3	4	5	6
c. Pursue related patents in order to induce patent holders to a deal	1	2	3	4	5	6
d. Bargain with patent holders	1	2	3	4	5	6
e. Pursue other technological activities	1	2	3	4	5	6
f. Try to obtain the technology through licensing, joint-venture or acquisition	1	2	3	4	5	6
g. Wait until patent expires	1	2	3	4	5	6

6 - Considering those patentable PRODUCT/ PROCESS inventions for which you have NOT filed a patent plication during the last three years, what proportion of these were motivated by:

PRODUCT

	Less than 10%	10-30	31-50	51-70	71-90	More than 90%
The difficulty in monstrating the patentability teria to patent examiners	1	2	3	4	5	6
The amount of information sclosed	1	2	3	4	5	6
The costs of applying for a tent	1	2	3	4	5	6
The ease of legally enting around a patent	1	2	3	4	5	6
The difficulty for other s to copy the invention	1	2	3	4	5	6
he difficulty in detecting ingement	1	2	3	4	5	6
The possibility of a patent being valid if contested	1	2	3	4	5	6
The costs of defending a nt in court	1	2	3	4	5	6
e ease of someone else cing you to cross-nsing	1	2	3	4	5	6
e rate of technological gress	1	2	3	4	5	6

II. PROCESS

	Less than 10%	10-30	31-50	51-70	71-90	More than 90%
a. The difficulty in demonstrating the patentability criteria to patent examiners	1	2	3	4	5	6
b. The amount of information disclosed	1	2	3	4	5	6
c. The costs of applying for a patent	1	2	3	4	5	6
d. The ease of legally inventing around a patent	1	2	3	4	5	6
e. The difficulty for other firms to copy the invention	1	2	3	4	5	6
f. The difficulty in detecting infringement	1	2	3	4	5	6
g. The possibility of a patent not being valid if contested	1	2	3	4	5	6
h. The costs of defending a patent in court	1	2	3	4	5	6
i. The ease of someone else inducing you to cross-licensing	1	2	3	4	5	6
j. The rate of technological progress	1	2	3	4	5	6

	Less than 10%	10-30	31-50	51-70	71-90	More than 90%
7 - In the last three years, hat percentage of your RODUCT inventions was ELIBERATELY carried ut by circumventing omeone else's patents?	1	2	3	4	5	6
8 - In the last three years, hat percentage of your ROCESS inventions was ELIBERATELY carried ut by circumventing meone else's patents?	1	2	3	4	5	6
9 - Over the last three ars, what proportion of the tent infringements against u was:						
Ignored	1	2	3	4	5	6
Resolved by simple tification	1	2	3	4	5	6
Resolved by out of court tlement	1	2	3	4	5	6
Resolved by court gation	1	2	3	4	5	6
0 - In the last three years, at percentage of your nted patents had been sciously designed to round someone else's ents in order to lead to a l?	1	2	3	4	5	6
1 - On average, up to what ent of a patent LIFE are prone to defend yourself nst infringements?	1	2	3	4	5	6

	Less than 10%	10-30	31-50	51-70	71-90	More than 90%
B12 - What proportion of your patent applications were filed motivated by the possibility of:						
a. Boosting your researchers' morale	1	2	3	4	5	6
b. Showing the productivity of R&D	1	2	3	4	5	6
c. Obtaining revenue through licensing-OUT	1	2	3	4	5	6
d. Getting a bargaining position to have access to another patent/ technology	1	2	3	4	5	6
e. Facilitating R&D co-operation with other inventors	1	2	3	4	5	6
f. Precluding others from freely copying your inventions	1	2	3	4	5	6
g. Avoiding others from patenting a similar invention	1	2	3	4	5	6
h. Preventing others from patenting variations of your invention	1	2	3	4	5	6
i. Increasing competitors' costs to invent around your patents	1	2	3	4	5	6
j. Avoiding infringement trials	1	2	3	4	5	6
k. Enhancing the reputation of your company	1	2	3	4	5	6
l. Signalling interest to others	1	2	3	4	5	6
m. Getting a better bargaining position in standard-setting	1	2	3	4	5	6
n. Misleading competitors as to your true technological path	1	2	3	4	5	6
o. Having access to a foreign market	1	2	3	4	5	6

13 - What percentage of our effort relating to patents re devoted to:	Less than 10%	10-30	31-50	51-70	71-90	More than 90%
Detecting patentable ventions	1	2	3	4	5	6
Preparing patent pplications to be filed	1	2	3	4	5	6
Gathering information om the company's ientists/ engineers	1	2	3	4	5	6
Searching prior art	1	2	3	4	5	6
Monitoring the prosecution your company's patent plications in patent offices	1	2	3	4	5	6
Mapping other company's tent activities	1	2	3	4	5	6
Detecting infringement ainst your company	1	2	3	4	5	6
Defending your company ainst infringement	1	2	3	4	5	6
Dealing with licensing ues	1	2	3	4	5	6

4 - What incentives do you give to your earchers in order to encourage them to perform entions which will generate patent applications?

ndividual assessment uenced by number of ent applications filed	☐ Yes	☐ No
erbal encouragement	☐ Yes	☐ No
ritten encouragement	☐ Yes	☐ No
roportionate financial ard	☐ Yes	☐ No

B15 - Overall, what proportion of your patent portfolio is characterized by:	Less than 10%	10-30	31-50	51-70	71-90	More than 90%
a. Patents with narrow scope	1	2	3	4	5	6
b. Patents with broad scope	1	2	3	4	5	6
c. Patents that surround someone else's patents	1	2	3	4	5	6
d. Patents that surround your own patents	1	2	3	4	5	6
e. Patents with prohibitive invent-around costs	1	2	3	4	5	6
f. Patents taken out in a less structured way due to uncertainties as to R&D direction or economic importance	1	2	3	4	5	6
g. Patents ordered in some way aimed to cover an array of technical solutions for achieving a similar functional result	1	2	3	4	5	6

The remainder of this Section concerns follow-up patent applications. Do NOT count as follow-ups those applications relating to the same invention filed later in other countries. Count as follow-ups only those filings which incorporate improvements on the initial conceptual idea, and which may lead to a broader protection of your final product/ process before it is launched/ used. If you do NOT file follow-up applications, please go to *SECTION C.*

B16 - On average, for each one of your priority filing how many follow-up applications are filed?

	Product Inventions	Process Inventions
a. From 1 to 2	☐	☐
b. From 3 to 4	☐	☐
c. From 5 to 6	☐	☐
d. From 7 to 8	☐	☐
e. From 8 to 9	☐	☐
f. More than 9	☐	☐

B17 - Which of the above applies to your most valuable inventions?

a. Product ________ b. Process ________

(Enter corresponding letter)

B18 - Regarding your follow-up applications, what share is filed:	Less than 10%	10-30	31-50	51-70	71-90	More than 90%
a. Within 12 months from priority filing	1	2	3	4	5	6
b. Between 12 and 18 months from priority filing	1	2	3	4	5	6
c. Between 18 months from priority filing and the issuance of the patent corresponding to the priority filing	1	2	3	4	5	6
d. After the issuance of the patent corresponding to the priority filing	1	2	3	4	5	6

Section C
About Your Patenting Activity

C1 - Approximately, what was your total cost of patenting activities and purchased services last year?

a. UK (*£'000s*) ____________

b. Abroad (*£'000s*) ____________

C2 - Approximately, what proportion of the total above corresponds to:	Less than 10%	10-30	31-50	51-70	71-90	More than 90%
a. Patent office fees	1	2	3	4	5	6
b. Salaries of employees engaged in this work	1	2	3	4	5	6
c. Payment to outside patent attorneys (excluding litigation lawyers)	1	2	3	4	5	6
d. Payment to specialised litigation lawyers	1	2	3	4	5	6

C3 - What percentage of your UK patents are going to have their term expired in:	Less than 10%	10-30	31-50	51-70	71-90	More than 90%
a. Less than 2 years	1	2	3	4	5	6
b. Between 2 and 5 years	1	2	3	4	5	6
c. Between 5 and 10 years	1	2	3	4	5	6
d. Between 10 and 15 years	1	2	3	4	5	6
e. More than 15 years	1	2	3	4	5	6

C4 - On average, for what percentage of your filings in the UK Patent Office is a patent granted?

a. ________%

5 - Compared to the average in your FOCUS
ndustry, the scope of most of your patents is:

Substantially broader ☐

Slightly broader ☐

No difference ☐

Slightly narrower ☐

Substantially narrower ☐

6 - Which one of these possibilities (**a** to **e**) best
pplies to your most valuable patents?

______ (Letter)

C7 - With your FOCUS industry in mind, how many dependent claims are drafted on average for each independent claim in your typical patents?

a. Less than 5 ☐

b. From 5 to 10 ☐

c. From 11 to 15 ☐

d. From 16 to 20 ☐

e. From 21 to 25 ☐

f. More than 25 ☐

C8 - Which one of the above best applies to your most valuable patents?

______ (Enter letter)

9 - Based upon the last calendar year, please give the approximate figures regarding your patent
pplications in the UK Patent Office (**UKPO**):

	2002
Total number of filings in the UKPO (including those, if any, coming from the Patent Co-peration Treaty route -**PCT**, European Patent Office -**EPO**, etc)	________
Proportion of "**a**" first filed in the UKPO before anywhere else (**priority filings**)	______%
Proportion of "**a**" corresponding to your company's FOCUS industry in the UK	______%
Percentage of "**a**" relating to inventions generated in the UK	______%
Number of patents pending in the UKPO	________

10 - During the last three years, in which **5**
OUNTRIES (the UK inclusive, if applicable) did
u file or designate (if using a supra-national route)
ost of your patent applications?

Country

1st ______________

2nd ______________

3rd ______________

4th ______________

5th ______________

you listed more than one country, please go to
e next question, otherwise go to question C12.

C11 - During the last three years, for what proportion of the filings in other countries did the following contribute most in motivating you to seek patent protection?	**Less than 10%**	**10-30**	**31-50**	**51-70**	**71-90**	**More than 90%**
a. Your company's current or foreseeable participation in the market	1	2	3	4	5	6
b. The closeness of the market	1	2	3	4	5	6
c. The size of the market	1	2	3	4	5	6
d. The presence of your main competitors	1	2	3	4	5	6
e. The local presence of world-class technical/ scientific competence	1	2	3	4	5	6
f. The strong enforcement climate	1	2	3	4	5	6
g. The lower costs associated with the patenting process (e.g. no translation costs)	1	2	3	4	5	6

C12 - Regarding your patent applications worldwide (**excluding the UK**), please give the following figures for the last calendar year:

	2002
a. Total number of filings which started their international phase via the PCT	______
b. Average number of countries designated through the PCT route	______
c. Total number of filings which started their international phase via the EPO	______
d. Average number of countries designated when using the EPO route	______
e. Total number of filings worldwide **(excluding the UK)**	______
f. Proportion of "**e**" corresponding to your FOCUS industry	______%
g. Number of patents pending worldwide **(excluding the UK)**	______

C13 - Please indicate the extent that you AGREE or DISAGREE with the following statements relating to patent activities in your FOCUS industry:

	Strongly Disagree	←		→		Strongly Agree
a. Information disclosed by other inventors' patents are essential to our R&D activities	1	2	3	4	5	6
b. Patents are decisive in increasing the returns from our innovative effort	1	2	3	4	5	6
c. The potential returns from a market is decisive for whether or not we will seek a patent	1	2	3	4	5	6
d. Our most valuable patents are those most frequently cited by our subsequent patents	1	2	3	4	5	6
e. We file patent applications early in the R&D process	1	2	3	4	5	6
f. Information disclosed by our patent applications harms our prospects of higher returns from the corresponding inventions	1	2	3	4	5	6
g. Our most valuable innovations would NOT bring high returns if they were NOT patented	1	2	3	4	5	6
h. Patents play a key role in reaping the returns from innovation when we are able to protect as many variations as possible of the invention	1	2	3	4	5	6
i. Securing patents is paramount if we want to have access to third parties' patented inventions	1	2	3	4	5	6
j. Our patents with broad scope are more valuable than our patents with narrow scope	1	2	3	4	5	6
k. Patents taken out early in the R&D process, increase our prospects of financing further development	1	2	3	4	5	6
l. The presence of very broad patents held by other inventors discourage us from seeking inventions in the same technology field	1	2	3	4	5	6
m. The more valuable a patent, the more it will be cited by other inventors	1	2	3	4	5	6

14 - With all your patent portfolio in mind, please give the following figures for the last calendar year:

	2002
Number of patent families (patents in force in different countries for the same original invention)	________
Total number of patents in force (**UK and abroad**)	________
Percentage of "**b**" relating to your FOCUS industry	________%
Percentage of "**b**" issued in the last calendar year	________%
Number of patents in force in the UK	________
Percentage of "**e**" relating to your FOCUS industry	________%
Percentage of "**e**" issued in the last calendar year	________%

Section D
About Your R&D Activity

1 - Over the past three years, approximately what rcentage of your R&D expenditures was:

Basic Research (scientific research th NO specific commercial jectives) ________%

Applied Research (scientific or gineering research with a specific mmercial objective) ________%

Design and/or Development chnical activity translating research dings into products or processes) ________%

Technical Service (e.g. providing nufacturing support, etc) ________%

100%

- Please **RANK** the countries (including the UK) ere most of your R&D expenditures were spent t year: (list at most 5, if applicable)

	Country	% Total R&D
1st	________	________%
2nd	________	________%
3rd	________	________%
4th	________	________%
5th	________	________%

D3 - Approximately, what percentage of your total R&D expenditure applies to your FOCUS industry?

% Total R&D ________________

D4 - During the last three years, how useful was the information disclosed by other inventors' patents/ patent applications to guide your R&D activities?

Not at all Useful ←→ Very Useful

1 2 3 4 5 6

D5 - Please **RANK** (starting with **1** for the **MOST** important) the reasons you had for using patent information:

a. To keep abreast of technological changes ____

b. To find information relating to a specific technological problem ____

c. To keep track of competitors ____

d. To check if an invention was already patented ____

e. To check on potential patent infringement ____

f. To obtain market information ____

D6 - Since the 1980's, at what rate have innovations been introduced by other firms in your FOCUS industry in the UK?

	Very Slow	⟷				Very Fast
a. Breakthrough product innovations	1	2	3	4	5	6
b. Incremental product innovations	1	2	3	4	5	6
c. Breakthrough process innovations	1	2	3	4	5	6
d. Incremental process innovations	1	2	3	4	5	6

7 - In your FOCUS industry the UK, how long does it ke on average for someone se to introduce a competing ernative to your:	Less than 6 months	6 months-2 years	2-5 years	5-10 years	10-15 years	More than 15 years
PATENTED product novations	1	2	3	4	5	6
NON PATENTED product novations	1	2	3	4	5	6
PATENTED production ocess innovations	1	2	3	4	5	6
NON PATENTED oduction process novations	1	2	3	4	5	6

- With your FOCUS industry in mind, how long do u take on average to come out with a NEW product process, if this is the main output of R&D) and to it ready to be commercialized?

_______ **Years / Months**
(figure) (circle as appropriate)

- When is a corresponding patent application first d?

Before / After Market introduction
cle as appropriate)

- How far from market introduction does it esent?

_______ **Years / Months**
(figure) (circle as appropriate)

	Less than 10%	10-30	31-50	51-70	71-90	More than 90%
D11 - In the last three years, for what proportion of your inventions were their foreseeable high returns decisive in seeking patent protection?	1	2	3	4	5	6
D12 - In the last three years, for what percentage of your R&D activities was the likelihood of securing a patent central in deciding whether or not to go ahead with a particular project?	1	2	3	4	5	6
D13 - During the last three years, approximately what proportion of your R&D activities were stopped or diverted because of the perceived weak patent protection that would be achieved?	1	2	3	4	5	6

D14 - Over the last three years, in order for you to move forward and be able to market your products/ processes how important to your operations was securing property rights over inventions linked to other firms' patented inventions?

Not at all Important	⟷				Very Important
1	2	3	4	5	6

THANK YOU VERY MUCH INDEED FOR YOUR CO-OPERATION!!!

COMMENTS

lease use the space below if there is anything else you would like to mention about patent activities ither within your company or within the industry your company operates.

espondent details

. years working on patents: __________

b Title: ____________________

Thank you for your time and assistance in completing this questionnaire.

☐ Tick here if you would like a custom report, and please provide the following details:

me:

mpany:

dress:

Appendix 8
Introductory Letter to the Patent Survey

WARWICK
BUSINESS SCHOOL

University of Warwick
Coventry CV4 7AL
Tel. 024 7652 2087
Fax. 024 7652 4650
h.m.barros@warwick.ac.uk

Marketing and Strategic Management Group

Date

Addressee

Dear ,

Patent activity in the UK

I hope that you will excuse a direct approach such as this but according to the Department of Trade and Industry *R&D Scoreboard* your company is one of the most innovative in the UK. I am carrying out a survey relating to the use and management of patents in UK industry and I would very much appreciate if your company could collaborate with this research.

A key element of my research involves the collection of information regarding patent activities from those people most closely involved with decision making on patenting. Within the next few days you will receive a request to complete a brief questionnaire relating to such decisions. If such decision making is not within the remit of your responsibilities I would be grateful if you could pass it to whoever does carry these responsibilities in your company or, in the case of a group of companies, within the company where most of the Research & Development expenses are incurred.

The survey is being conducted in an effort to better inform policy makers, academics, and others who must make decisions related to patents. Confidentiality can be assured in that no source of material will be explicitly named in the research output.

With many thanks in anticipation of your help. If you would like any further information about this research, you may contact me on the address/ telephone above or by E-mail at H.M.Barros@warwick.ac.uk.

Yours sincerely,

Henrique Barros
Principal Research Officer

Appendix 9
Cover Letter to the Patent Survey

WARWICK
BUSINESS SCHOOL

University of Warwick
Coventry CV4 7AL
Tel. 024 7652 2087
Fax. 024 7652 4650
h.m.barros@warwick.ac.uk

Marketing and Strategic Management Group

Date

Addressee

Dear ,

Patent activity in the UK

A week or so ago you will have received a letter giving a brief introduction to a survey on patent activity that is being carried out amongst the most innovative companies operating in the UK. Knowing how companies view the importance of patents - and how patents are used – is vital not only to policy makers but also to those who make decisions about patents within their own companies in order to benchmark with others.

Naturally, it is important to collect information from those people most closely involved with decision making on patenting, and the questionnaire was designed following consultation with other UK companies. I am requesting your collaboration with this project by asking you to take the few minutes necessary to complete the brief questionnaire appended to this letter, and by returning it in the postage paid envelope provided. If decision making on patents is not within the remit of your responsibilities I would be grateful if you could pass it to whoever does carry these responsibilities in your company or, in the case of a group of companies, within the company where most of the Research & Development expenses are incurred.

You may be assured confidentiality in that no source of material will be explicitly named in the published results.

Should you wish to make further enquiries about this survey, you may contact me on the address/ telephone above or by E-mail at H.M.Barros@warwick.ac.uk.

I very much hope that you will be able to accede to this request and would like to express my gratitude in advance for your time and assistance.

Yours sincerely,

Henrique Barros
Principal Research Officer

Appendix 10
Follow-up Letter to the Patent Survey

WARWICK
BUSINESS SCHOOL

University of Warwick
Coventry CV4 7AL
Tel. 024 7652 2087
Fax. 024 7652 4650
h.m.barros@warwick.ac.uk

Marketing and Strategic Management Group

Date

Addressee

Dear ,

Patent activity in the UK

Please accept our apologies for disturbing you. A questionnaire on patent activity was mailed to you the week before last week. We are therefore contacting you again to ask for your cooperation. If you, or someone else within your company, have already completed and returned the questionnaire, please accept our sincere thanks. If not, could you please do so as soon as possible? It is important that we receive back as many completed questionnaire as possible so that the results of the survey will be fully representative of firms operating in the UK.

We are especially grateful for your help because we believe that what we learn in response to the questionnaire will be very useful to both policy makers and those who make decisions about patents. However, if you did not receive a questionnaire, or if it was misplaced, please do not hesitate to contact us on the above telephone/ email and we will get another one in the mail to you shortly.

Yours sincerely,

Henrique Barros
Research Officer

Appendix 11
Analysis of Variance of a Series of Attributes of Respondents and Non-Respondents to the Patent Survey

R&D expenses in 2000 (£ M)

Source	SS	df	MS	F	Prob > F
Between groups	275.822	1	275.822	0.01	0.9267
Within groups	12793301.0	393	32552.93		
Total	12793576.9	394	32471.01		

Bartlett's test for equal variances: chi2(1) = 32.1765 Prob>chi2 = 0.000

Sales in 2000 (£ M)

Source	SS	df	MS	F	Prob > F
Between groups	222654746	1	222654746	4.03	0.0454
Within groups	2.1442e+10	388	55263536.7		
Total	2.1665e+10	389	55693848.3		

Bartlett's test for equal variances: chi2(1) = 114.3320 Prob>chi2 = 0.000

Profits in 2000 (£ M)

Source	SS	df	MS	F	Prob > F
Between groups	1565162.36	1	1565162.36	1.24	0.2668
Within groups	487348306	385	1265839.75		
Total	488913468	386	1266615.20		

Bartlett's test for equal variances: chi2(1) = 50.0782 Prob>chi2 = 0.000

R&D per employee (£ 000's)

Source	SS	df	MS	F	Prob > F
Between groups	2557.19	1	2557.19	2.13	0.1448
Within groups	460070.32	384	1198.10		
Total	462627.51	385	1201.63		

Bartlett's test for equal variances: chi2(1) = 10.0210 Prob>chi2 = 0.002

Appendix 12

Analysis of Variance of a Series of Attributes of Respondents to Different Waves of the Patent Survey

R&D expenses in 2000 (£M)

Source	SS	df	MS	F	Prob > F
Between groups	635.62	1	635.62	0.10	0.7569
Within groups	228617.51	35	6531.93		
Total	229253.13	36	6368.14		

Bartlett's test for equal variances: chi2(1) = 9.2108 Prob>chi2 = 0.002

Sales in 2000 (£ M)

Source	SS	df	MS	F	Prob > F
Between groups	66596241.2	1	66596241.2	0.25	0.6234
Within groups	9.4966e+09	35	271332674		
Total	9.5632e+09	36	265645551		

Bartlett's test for equal variances: chi2(1) = 27.8427 Prob>chi2 = 0.000

Profits in 2000 (£ M)

Source	SS	df	MS	F	Prob > F
Between groups	2572668.06	1	2572668.06	0.60	0.4449
Within groups	146437538	34	4306986.42		
Total	149010206	35	4257434.47		

Bartlett's test for equal variances: chi2(1) = 28.4897 Prob>chi2 = 0.000

R&D per employee (£ 000's)

Source	SS	df	MS	F	Prob > F
Between groups	4826.53	1	4826.53	2.19	0.1484
Within groups	75031.44	34	2206.81		
Total	79857.97	35	2281.66		

Bartlett's test for equal variances: chi2(1) = 28.2184 Prob>chi2 = 0.000

Appendix 13
Proportion of Firms' Patent Policies by Firm Size Band

Product innovations

Size band	Do not patent	Patent inventions of own interest	Patent inventions of own interest or of others'	Patent everything
< 50	0.00	0.00	18.18	50.00
50-249	14.29	10.00	18.18	25.00
250-499	28.57	10.00	18.18	0.00
500-999	14.29	0.00	0.00	0.00
1000-4999	28.57	60.00	0.00	0.00
5000-19999	14.29	10.00	27.27	25.00
> 19999	0.00	10.00	18.18	0.00
Total (%)	100.00	100.00	100.00	100.00

Process innovations

Size band	Do not patent	Patent inventions of own interest	Patent inventions of own interest or of others'	Patent everything
< 50	0.00	0.00	5.26	50.00
50-249	33.33	11.11	15.79	16.67
250-499	33.33	33.33	10.53	0.00
500-999	0.00	0.00	0.00	16.67
1000-4999	33.33	55.56	26.32	0.00
5000-19999	0.00	0.00	26.32	16.67
> 19999	0.00	0.00	15.79	0.00
Total (%)	100.00	100.00	100.00	100.00

Appendix 14
Average R&D Intensity (%) by Patent Policy

Product Innovations

Policy	mean	sd	min	max
Do not patent	3.20	3.34	0.26	6.83
Patent inventions of own interest	7.98	7.22	1.56	22.86
Patent inventions of own interest or of others'	54.64	151.09	0.29	620.00
Patent everything	124.08	216.89	0.90	503.00

Process Innovations

Policy	mean	sd	min	max
Do not patent	3.26	2.24	0.26	6.83
Patent inventions of own interest	7.20	7.09	0.91	22.86
Patent inventions of own interest or of others'	84.74	191.66	0.29	620.00
Patent everything	204.94	263.74	1.81	503.00