STUDY ON EVALUATING THE KNOWLEDGE ECONOMY - WHAT ARE PATENTS ACTUALLY WORTH?

THE VALUE OF PATENTS FOR TODAY'S ECONOMY AND SOCIETY

Tender n° MARKT/2004/09/E

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1. ORGANIZATION OF THE REPORT

This Report deals with the economic value of European patents and offers a comprehensive analysis of the "state of the art" on this issue. It provides a complete survey of the existing scientific literature in economic and business studies, and it uses original data to present descriptive statistics and elaborations on the value of European patents.

The survey of the literature and the empirical analysis are organised around two main headings:

A. The direct benefits of patents, both actual and potential effects.

B. The indirect benefits of patents, such as the effects on employment and the knowledge spillovers that they produce.

Section 2 describes the methodology adopted for the survey of the literature, and the database on the surveyed scientific publications that we built by country, technology and type of applicant organization. Section 2 is organised in 4 Themes: (A1) The economic value of patents; (A2) The utilization of patents and the potential for enhancing their value; (B1) New firm creation and employment; (B2) The impact of patent protection on knowledge spillovers and productivity. The first and second Themes go under the heading "The *direct* economic effects of patent protection"; the third and fourth Themes deal with "The *indirect* effects of patent protection".

Section 3 presents and discusses selected Tables of descriptive statistics based on the PatVal-EU dataset on 4 research Themes that are closely related to those explored in the survey of the literature: (A1) The value and social costs of patents; (A2) The economic use of patents and the importance of different motives for patenting; (B1) The creation of new businesses from the patented innovation; (B2) Collaboration, spillovers and the sources of knowledge in the innovation process. We provide Tables of descriptive statistics by country, technologies and type of applicants' organization.

Section 4 finally reports descriptive statistics on the patent explosion at the EPO by showing the patent counts and the contribution to the growth of EPO patents from 1986 to 2001 by broad regions (EU25, EU15, New Member States, US and Japan) and by "macro" technological classes.

Section 5 summarises the results and concludes with a detailed plan of research for Lot2 of this project.

The Annexes at the end of the Report provide additional empirical evidence on the issues discussed in this work. Annex I describes the structure of the dataset that has been built in order to develop a comprehensive literature survey on the four themes of this tender. Annex II includes a set of Tables showing the systematic analysis of the coverage of the literature by theme, country, technology, type of inventors' employer and type of contribution to the literature (i.e. theoretical or empirical). Annex III reports additional Tables of descriptive statistics based on the PatVal-EU dataset.

2. LITERATURE SURVEY

The survey of the literature provides a comprehensive overview of the existing studies on the direct and indirect impact of patents in different countries, sectors and technologies. The methodology employed for the survey follows three steps:

a. Literature search

b. Classification of the literature

c. Analysis of the literature by theme

2.1 Literature search and classification

The methodology for the search, collection and classification of the literature relied both on the expertise of the team members, and on the systematic search for references. This ensured a comprehensive coverage of the "state of the art" on the topics under investigation.

First of all, the team experts provided us with a list of relevant papers on each research Theme. By using these papers we identified a number of key-words and conceptual maps for a systematic search of the literature. We performed the latter by browsing computerized and printed searching tools available at Sant'Anna School of Advanced Studies and at INSEAD: EconLit, International Bibliography of the Social Sciences, Social Sciences Index, Jstor, ABI Inform, Business Source Premier, Helecon, The Georges and Edna Doriot Library, NBER Working Paper Series and the Research on Innovation Web site. We also searched for publications and reports of the OECD, the European Commission, and other international organizations.

We collected articles, books, working papers and reports that deal with broad themes and aggregate analysis. We also found contributions that analyse specific themes by means of disaggregated levels of analysis (e.g. specific countries, technologies, and case studies). We select the relevant publications and we assess their quality by using the team expertise and the codified rules of evaluation based on the number of citations received by the articles (source: Social Science Citation Index), the impact factor of the journal and the quality of the publisher. As far as the use of citations is concerned, we had to solve two problems. First, they are not available for reports, books and book chapters. We therefore checked for the quality of the publisher. Second, due to a "truncation" effect, recent articles receive a smaller number of citations than older papers. In order to limit this problem we used the impact factor of the Journal.

Section 2.2 presents the Review of the literature that we collected. In addition, we constructed a dataset that classifies the surveyed publications by using the following criteria: research Theme, country, technological area, empirical vs. theoretical paper, abstract, main contribution of the publication. Annex 1 describes the structure of the database.

2.2 Analysis of the Literature by Theme

Theme A1. Economic Value of Patents

A1.1 Overview on the Economics of Patenting and some Recent Theoretical Contributions

The classical theoretical contribution on the basic economics of IP is that of Nordhaus (1969). The theory highlights that the main benefits of patent protection are to stimulate innovative investments and promote the diffusion of technological knowledge. Indeed, by providing restrictions to the use of patented inventions, patent law provides the ability to recover the investment needed to introduce technological innovations, in exchange of the disclosure of the technical details of the patented inventions to the public. The main social cost is the restriction in use, and thus the inefficiencies associated with monopoly protection.

Nordhaus economic framework has been extended, especially during the 90s. These extensions relate to the design of optimal patent policy, and have focussed mainly on two dimensions of patent protection: its length and scope (or breath). A broader scope refers to a broader area of technology space from which others are excluded. Gallini (1992) operationalises this concept as the cost that rivals must incur to imitate an invention without infringement. No matter how scope is defined, however, a broader patent increases the market price for the invention. The main conclusion from this literature is that in world where both licensing and commercialisation are feasible alternatives to profit from the invention, a case can be made for narrow and long patents. Important extensions of these theories during the 90's (cf. Gallini, 2002 for an excellent and succinct review on this topic) suggest that policies that broaden the scope of patents do not however unambiguously stimulate innovation in industries characterized by cumulative technical change. Indeed, broad and short patents are indicated as superior policy in the case of cumulative innovations because they prevent duplicative R&D, stimulate the introduction of improvements and protect early innovators. Despite its theoretical importance, the empirical literature on the impact of patent scope on R&D incentives is surprisingly limited, as evidenced in the following sections.

A1.2 The Value of Patent Protection from Survey Data

Prior empirical work has tried to evaluate the effectiveness of patent protection in stimulating innovation largely through survey-based studies. The evidence has been interpreted as suggesting that the inducement provided by patents for innovation is small in most industries. The studies by Scherer et al. (1959), Taylor and Silberston (1973), Mansfield et al. (1981), Mansfield (1986) suggest that patent protection may not be an essential stimulus for the generation of innovation in most industries. The survey findings of Levin, Klevorick, Nelson and Winter (1987) and, more recently, Cohen et al. (2000) suggest that in most industries patents are less featured than other means of protecting innovations, such as first mover advantages or secrecy. Similar results were obtained for Europe (Arundel et al., 1995) and Japan (Goto and Odagiri, 1997).

A1.3 The Value of Patent Protection from Patent Renewal and Application Data

The literature has traditionally used patent data as indicators of inventive success of the underlying innovative effort (Griliches, 1990; Archibugi and Pianta, 1996). The objective was to uncover the causes and consequences of inventive activity, and not to directly evaluate the impact of patent protection on innovation. An important exception is given by the studies that use patent renewal data, where the focus is on explaining the value of patent rights.

In many countries, it is necessary to pay a renewal fee each year in order to keep a patent in force. The rationale for using the patent renewal fees as an indicator of the value of patent protection is that they are paid only if the expected future returns of the patents are higher than the costs of keeping the patent rights, viz. the renewal fee itself. Hence, when the renewal fee is not paid, the patent has expected returns lower than the threshold (Pakes and Schankerman, 1984; Pakes, 1986; Schankerman and Pakes, 1986; Schankerman, 1998; Lanjouw, Pakes and Putnam, 1998).

This literature finds differences across European countries. For example, Pakes (1986) found that in France one percent of the patents has a value higher than 70,000 US dollars, while in Germany one percent of the patents have value higher than 120,000 US dollars.

Schankerman (1998) uses patent renewal data to estimate the value of the cash subsidy to R&D conferred by patent protection in France, which he calls the equivalent subsidy rate (ESR) to company-funded R&D due to patent protection. The ESR is calculated by dividing the total value of patent rights by total R&D. It corresponds to the subsidy that firms would need in order to maintain R&D at current levels in the absence of patents. It also reflects the average return to R&D conditional on patent protection. Estimates suggest returns around 15%. To question whether this is enough an incentive for innovation, Pakes and Simpson (1989) argue that: "Compared with other institutionally created incentives (such as tax breaks), an 11 to 16 percent increase in returns does not seem small". They also add that "Of course, to judge the effectiveness of this incentive, one would need an estimate of the R&D response to the increase in returns, and then a way to compare the benefits from that response, plus whatever benefits there are from publicizing the content of the patent, with the costs of patent protection." Without a model that links such values to R&D investments, the patent renewal models cannot accomplish such a task. In the next section we will survey the literature that more recently has tried to accomplish such a task.

Interestingly enough, since data on patent renewal fees were available only for the European patents, this research has focused on them. Putnam (1996) used patent applications data to uncover the value of international patent protection, and he showed that this is higher than the one found by using patent renewal data (see also Deng, 2003, for a recent extension of this approach). However, results are not directly comparable to those obtained by the patent renewal models, given that he used only patents for which an international extension was applied for. Arora, Ceccagnoli and Cohen, (2003) used the number of patent applications, the propensity to patent, and R&D data to compute the *patent premium*, a concept closely related to the value of patent rights computed by the patent renewal models. They find that patents, on average, are not effective, in the sense that they provide a positive expected premium – i.e. greater net expected returns from patenting an innovation relative to not patenting it – for only a small fraction of innovations. In fact, on average, the relative magnitude of benefits and costs suggests that firms expect to loose about 50% of the value of an innovation by patenting it. However, for the innovations that firms choose to patent, firms expect to earn - on average - a 50% premium over the no-patenting case. Their model, although confirming that most patented innovations have small conditional premia due to the skewness of the distribution of the premia conditional on patenting, also presents evidence that the average expected premium for patented innovations is much larger than the average expected premium for all innovations.

A1.4 The Impact of Patent Protection on R&D and Innovation

Among the first studies that focussed on the relationship between patents and R&D are the contributions by Pakes (1985), and Griliches, Hall and Pakes (1991). The main objective of these earlier studies was to uncover the determinants of inventive activity. In particular, these authors tried to disentangle the impact of supply-side factors (such as technological opportunities) and demand factors on the rate of technical change. After controlling for firm R&D, changes over time in the unobserved factors that affect the number of patents granted to a firm were interpreted as capturing supply-side changes in R&D activity. They could either represent technological opportunities, or firms' propensities to patent. The lack of direct measures for patent propensity, however, did not allow them to address the impact of patent propensity on R&D, which seems to be a key determinant of the expected returns to R&D as conditioned by the existence of the patent system.[1]

This latter point was addressed by Arora et al. (2003). By using firm-level data from the Carnegie Mellon Survey (CMS), this is the first study on the impact of changing the value of patent rights on innovation. Their model takes into account the fact that patenting and R&D decisions are driven by common factors, including the appropriability incentive of patenting and the offsetting role of patents in producing R&D spillovers. Their model further recognizes that if one firm benefits from stronger patent protection in a specific area, also its competitors will benefit from it. The results of this work show that patents have the greatest positive incentive effect on research and development (in the sense that an increase in the premium generates a positive a substantially positive response in R&D) in pharmaceuticals, biotechnology, medical instruments, and computers. In semiconductors and communications equipment the premium and the incentive effect are much lower, although still positive and not negligible. In considering the impact of patenting on the R&D conducted by the industry incumbents, this analysis does not consider the impact of the uses of patents on industry entry. However, to the extent that entry is associated with innovation, this could have important implications for innovation.

Despite substantial theoretical work on the impact of patent scope on innovation and social welfare, there is only one study (Sakakibara and Branstetter, 2001) that directly analyses the impact of patent scope on innovation. By using panel data on a sample of manufacturing firms in Japan, this study finds that there is only a small positive effect of increasing patent scope on R&D investments.

[1] A related literature has examined the determinants of patenting, measured as the number of patent applications or grants. This literature focussed on the estimation of patent production functions, with R&D and knowledge spillovers as the main inputs. For a recent survey and extensions of this work see, among others, Cincera (1997). See also the work by Licht and Zos (1996) for the case of Germany.

All the contributions that used cross-national aggregate data have instead found a positive and significant effect of the strength of patent protection on R&D (Eaton and Kortum, 1999; Kanwar and Evenson, 2003; Maloney and Lederman, 2003). Given the results of the existing studies on this issue, there seems to be a need for additional empirical work to evaluate the impact of patent policies on R&D incentives within specific countries and over time along the lines of Sakakibara and Branstetter (2001).

A1.5 The Impact of Patent Protection on Firm Performance

One approach to assess the value of patents estimates the impact of the patent stock of firms on their stock market value after controlling for their stock of R&D and physical capital (Pakes, 1985; Bloom and Van Reenen, 2002; Hall, Jaffe and Trajtenberg, 2005). This literature has consistently estimated a positive and significant marginal value of the patent stock. Bloom and Van Reenen (2002) found that doubling the citation weighted patent stock would increase the value of UK public firms per unit of capital by about 35%. This captures the change in the market expectation of the discounted rents from the patented innovations. A positive, but somewhat lower response was found by Hall, Jaffe and Trajtenberg (2005) for the US. They also report that, for the US, an extra citation per patent boosts market value by 3%.

Most of this literature suffers from the inability to disentangle the impact of patent protection on firm performance from the impact of innovation itself. This is also the case of Lerner (1994), for example, who looks at the impact of patent scope on the market value of a sample of US biotech companies. He finds that a one standard deviation increase in the average patent scope is associated with a 21% increase in the firm's value. However, it is not clear whether this study captures the impact of innovation on performance as opposed to the benefits of patent protection over and above the profits derived from alternative appropriation strategies.

A1.6 Patent Citations and the Value of Patents

Quite a few studies have found that the economic value of patents is correlated with their citations. The traditional contribution is Trajtenberg (1990), who computed a measure of social returns to innovation in the computer-tomography scanner industry. He also found a positive and significant correlation between this measure and patent citations.

Since citations to US and European patents became widely available (e.g. see Hall, Jaffe and Trajtenberg, 2001), several studies in the literature used them as indicators of the value of patents, or at least of their importance. None of the subsequent studies, though, has made an explicit link between patent citations and the social and private value of patents.

A1.7 Multiple Indicators for Patent Value

Recent contributions found that several indicators can be used as proxies for the value of patents, e.g. oppositions, family size, number of claims, backward and forward citations. Harhoff, Scherer and Vopel (1999) used survey data obtained on 964 inventions made in the US and Germany, and on which German patent renewal fees were paid to full-term expiration in 1995. They found that patent citation counts are positively associated with patent renewal fees and with the private economic value of patents. Harhoff, Scherer and Vopel (2003) combined estimates of the value of patent rights from a survey of patent-holders with a set of indicator variables in order to model the value of patents. Their results suggest that the number of references to the patent literature as well as the citations a patent receives are positively related to its value. Harhoff and Reitzig (2004) analyse the determinants of oppositions (the most important mechanism by which the validity of a European patent can be challenged) to biotechnology and pharmaceutical patents granted by the EPO between 1978 and 1996. They find that the likelihood of opposition increases with the value of the patent. Sherry and Teece (2004) use the success rate of patent lawsuits in the US to measure the change in the patent value over time, and in particular that part of the change due to changes in the legal environment. Finally, Guellec and van Pottelsberghe (2002) present systematic international comparisons for the OECD area on the determinants of the probability for a patent application to be granted, which is interpreted as signalling the value of the invention.

A1.8 Patent Value from Survey Data

The literature has usually used indirect measures of the economic value of patents. Survey data can provide direct measures of the value of patents as one can ask the inventor or any relevant individual in the applicant organization direct information on patent value. There are only few studies that employ survey information on the economic value of patents. One rigorous survey is the one conducted by Harhoff, Scherer and others (Scherer and Harhoff, 2000; Harhoff, Scherer and Vopel, 2003b). These studies cover only German and US patents. One limitation of survey data is that the inventors or the assignees may provide a subjective answer to the question on the value of their patents, either because they do not know with precision the actual economic returns of their patents, or because they do not want to disclose it.

These studies have also shown that the distribution of patent values is highly skewed, with a spike at zero. Research on the skewness of the patent value distributions includes Harhoff, Scherer, and Vopel (2003b), Scherer and Harhoff (2000), and Harhoff, Narin, Scherer and Vopel (1999).

The empirical literature focuses mainly on the US. Exceptions are Harhoff and Reitzig (2004), Harhoff and Hall (2002) and Bekkers, Duysters and Verspagen (2002) that also include some European countries. Methodological and empirical investigations are available for the US and the UK, but not for the EU in general (Bloom and Van Reenen, 2002; Hall, Jaffe and Trajtenberg, 2001; Greenhalgh, Longland and Bosworth, 2001).

A1.9 Value of Patents and their quality: Trends over time

Given the rapid growth in patenting, an important question is whether the quality of such patents, and thus their value, has declined. If patents do not meet the novelty and utility thresholds, the social costs due to monopoly protection are more likely to outweigh the benefits conferred by patents.

Along this line, Hall and Ziedonis (2001) conjectured that much of the increase in patenting in semiconductors reflected “harvesting” behaviour—that is the patenting of inventions that would have been invented in any event, and that, as a consequence, one would have expected a decline in quality. Hall and Ziedonis did not, however, find a clear decline in quality, measured as the average number of citations per patent in semiconductors. Consistent with this finding, Lanjouw and Schankerman (2003) actually find a positive relationship between portfolio size and the number of forward citations per patent. In information technology more broadly, and by using a normalized measure of the number of times the previous five years patents are cited in the current year, Hicks, Breitzman, Olivastro and Hamilton (2001) found an increase in patent quality over time. However, these tests of the quality of patents that rely on forward citations do not make the case that the patents that have been issued over the recent past have declined in terms of the standards of novelty, non-obviousness, and utility (Cohen, 2004). On this issue, a recent study by the US National Research Council (2004) states that "…the claim that quality has deteriorated in a broad and systematic way has not been empirically tested."

A1.10 Other Social Costs of the Patent System

There is some evidence suggesting that litigation costs have increased in the US, especially per dollar of R&D spending. There is also evidence that the costs of prosecuting patents have grown rapidly, and the costs per case have grown (National Research Council, 2004, p. 31). It is not clear, however, whether these costs have grown due to any increase in the strategic use of patenting (i.e. defensive or blocking patents). On this topic, see section A2.2.

Cesaroni and Giuri (2005) have recently reviewed the empirical literature on the extent and the costs of litigation. The statistics on litigations show that the crude number of patent suits filed in the US has constantly grown during the last two decades – although with some differences among different technological areas – following the constant increase of patenting over the same period of time. For instance, in a recent study, Lanjouw and Schankerman (2003) analyse the filing rates by different technology fields (drugs, other health, chemicals, electronics, mechanical, computers, biotechnology, and miscellaneous) during three time periods: 1978-84, 1985-90 and 1991-95. They show that the propensity to litigation varies among fields. However, when time trends are considered, and once the growth in patenting is taken into account, the study shows that no increase in litigation (in relative terms) occurred in any technological field. Furthermore, very few patent suits actually go to trial. Approximately 95% of all patent suits settle either before or during trial. In particular, 78% settle before the pre-trial hearing, an additional 16% settle before trial, and 1% settle during trial. Even though most patent suits end up with a settlement before or during trial, about half of the estimated legal costs of litigation are incurred before the end of the discovery phase (AIPLA, 2001), thus making litigation extremely costly. Moreover, from a social perspective, settlements before trials are likely to lead to collusive outcomes, hence generating a social loss of resources.

In the literature survey of Cesaroni and Giuri (2005) it is also stressed that, apart from direct costs, patent litigations generate indirect costs whose relevance is even more important for the society on the whole. Often, rather than the actual amount of legal costs associated to litigations, it is the risk of incurring in such costs to create negative effects and to induce firms to modify their behaviours accordingly. In industries where patent protection is stronger, the risk of being suited for patent infringement and hence incurring the direct legal costs associated to a trial creates a barrier to entry, and prevents firms from investing in innovations. In turn, contrarily to policy expectations, a system of strong property rights might reduce the overall level of investments in R&D and innovative activities, especially for small firms that are most exposed to the risks of patent litigations. Since small firms often lack the required financial resources to sustain long and costly litigation causes, they under-invest in those areas where patent protection of large firms is higher. The empirical evidence can be found in Lerner (1995), Lanjouw and Lerner (2001) and Lanjouw and Schankerman (2003).

Theme A2: Utilization of Patents and Potential for Enhancing their Value

A2.1 Impact of patent protection on markets for technology

IPRs and especially patents have been thought of primarily in terms of providing incentives for innovation, as reflected by the studies described in the previous section. However, following Coase, economists have also argued that the definition of property rights in innovation will also make them easier to exchange. Lamoreaux and Sokoloff (2001), point to the information disclosure aspect of patents. Arguably, stronger patents can reduce transaction costs in technology licensing contracts (Arora, 1996; Arora and Merges, 2004).

Insofar as stronger patents also enhance bargaining power of the technology holder, this encourages firms to offer technologies for licensing or technological capability for hire (Gans, Hsu and Stern, 2002; Arora and Fosfuri, 2003). Thus, unused technologies find more willing buyers and innovators incapable of exploiting their innovations (or unwilling to do so) can appropriate the rents from their innovation by licensing or selling their innovation to others. In many instances, start-up firms in industries such biotechnology, semiconductors, instruments and chemicals have used their intellectual property as a means to obtain financing and corporate partners, both of which are critical for the successful commercialisation of new knowledge. In other words, it is plausible that by making possible the market exchange of new knowledge, the patent system contributes to a more efficient use of new knowledge.

However, though plausible, systematic and direct empirical support is limited. There are a handful of papers, and many of them have limitations as well. Arora (1996) shows that, for a sample of technology import agreements signed by Indian firms, technical services are more likely to be bundled into licensing contracts if patents are also present. Cassiman and Veugelers (2002) do not find that the patent strength encourages Belgian firms to enter collaborative R&D agreements. By using a sample of MIT inventions, Gans, Hsu and Stern (2002) find that the presence of patents increases the likelihood that an inventor will license to an incumbent rather than enter the product market by commercialising the invention. These studies tend to have small samples, limited or no variation in patent strength, and they are industry specific. Nakamura and Odagiri (2003) find that stronger IP protection tends to decrease transaction costs and to stimulate technology transactions between Japanese manufacturing firms. Mixed empirical evidence on the impact of patenting on international licensing using cross-national data has been recently presented by Fink and Maskus (2005).

Anand and Khanna (2000) come the closest to a systematic cross-industry comparison. They find that in chemicals there are many more technology deals than in other sectors, a large fraction of them involve arms length licensing deals, a large fraction of them involve exclusive licenses, a small fraction of deals are among related firms, and there is a large fraction of ex-ante deals (where the contract is about future rights, rather than rights on existing technologies). Anand and Khanna (2000) speculate that this is due to two inter-related factors. First, biotechnology and pharmaceuticals have stronger links to science so that the underlying knowledge base allows for technological knowledge to be articulated easily (Arora and Gambardella, 1994). Second, patents are more effective in chemicals, and especially in biotech and pharmaceuticals.

Finally, systematic evidence in support of a positive effect of patent protection on technology licensing is found in Arora and Ceccagnoli (2005). They find that an increase in the effectiveness of patent protection increases licensing propensity when complementary assets required to bring new technologies to market are absent or unimportant. By contrast, when firms are better positioned to bring new technologies to the market, increases in patent effectiveness increases patenting propensity but reduces the propensity to license. They present systematic cross-industry empirical support for the US manufacturing sector in favour of the proposition that patent protection is a key determinant of the market for technology, but that its impact is critically mediated by the ownership of specialized complementary assets.

Note that this effect of the patent system is closely linked to that of encouraging the generation of innovations. Indeed, to the extent that firms can more easily profit from patented innovations by licensing them to other firms that have the complementary commercialisation assets, the impact of patenting on licensing is a secondary key channel through which patent protection stimulates further investments in new technology. To our knowledge, however, there is no empirical study that has evaluated the R&D incentive effect of patent licensing.

A2.2 Impact of patent protection on other dimensions of firms' technology strategies

Only very few patents yield economic returns, as it is also confirmed by the skewness of their value distribution. Many patents are not used commercially simply because the inventors or the assignees do not have adequate assets to exploit them (e.g. small firms, individual inventors, scientific institutions). There are also many patents applied for by large firms that are never used. This is often the outcome of strategic behaviour.

This is not surprising, as a patent can be exploited commercially by using own complementary assets, or it can be licensed out, or it can be used for strategic purposes. The patenting option opens up such strategic opportunities in addition to licensing (Hall and Ziedonis, 2001; Cohen, Nelson and Walsh, 2000; Shapiro, 2000; Rivette and Kline, 2000).

Earlier studies on this issue focused on the use of patents to build strategic entry barriers and to preserve monopoly power (Gilbert and Newberry, 1992, for the basic theoretical piece). Early empirical evidence on such use is reported by Bunch and Smiley (1992) for the US. They show that for newly developed products, strategic entry deterrents, such as patents, are used more often when markets are concentrated and populated by large and research intensive firms. Other studies on the extent and the effectiveness of such strategic uses across manufacturing industries and countries are: Bessen and Hunt (2004) for software patents; Goto and Odagiri (1997) for Japan; Arundel, van de Paal and Soete (1995), Blind and Thumm (2004) and Reitzig (2004) for Europe; Cohen, Nelson and Walsh (2000) for the US. In particular, Cohen, Nelson and Walsh (2000) show that it is quite common to patent technologies around a certain invention to avoid that others use it even if they do not plan to exploit that invention (i.e. "blocking patents").

Systematic empirical evidence on whether patent thickets, extensive cross-licensing and the associated accumulation of large patent portfolios among incumbents -- common in industries such as computer, electronics and semiconductors -- create or reinforce barriers to entry, is still weak. Scholars such as Hall and Ziedonis (2001), Cohen, Nelson and Walsh (2000) and Shapiro (2000) suggest that the use of patents in portfolio exchanges among large incumbents may actually deter entry into the semiconductor and in other complex product industries. Strategies of patent portfolio expansion as responses to hold-up problems in the US semiconductor industry have been recently analysed by Ziedonis (2003).

The possibility that access to a patent on a key upstream technology may be blocked, impeding subsequent innovation and commercialisation, has attracted particular attention recently in biomedicine, especially around the impact of the patenting and licensing of "research tools," which include any tangible or informational input into the process of discovering a drug or any other medical therapy or method of diagnosing disease (cf. Heller and Eisenberg, 1998). To assess the degree to which either restrictions on access to upstream discoveries or anticommons are indeed hampering biomedical innovation, Walsh, Arora and Cohen (2003) conducted 70 interviews with scientists and executives employed by firms, intellectual property practitioners, and university and government personnel. They found that patents are indeed now associated with new therapeutic products, and there is more patenting of upstream discoveries since the Bayh-Dole Act, especially on the part of universities. They did not find, however, that these developments are impeding the development of drugs or other therapies in a significant way, at least not yet. Also, for commercially worthwhile projects, they found no evidence of breakdowns in negotiations over rights, or firms avoiding projects due to the prospect of an anticommon. The major reason is that firms and other institutions have developed "working solutions" that limit the effects of the intellectual property complexities that exist, such as licensing and occasional litigation.

Theme B1: New Firm Creation and Employment

As discussed by several studies, smaller firms specialised in the production of new technologies can be a major factor in enhancing the employment and economic performance of specific regions. This is why a patent system that allows for the formation of such firms can raise employment.

However, there are a few studies at the macro level on the relationships between patent protection and economic growth. From a theoretical point of view a classic study is that of Helpman (1993), who shows how in a North-South endogenous growth model, where the North innovates and the South imitates, the strengthening of IPRs stimulates innovation and growth of the North and hurts the imitator when the rate of imitation is high. The available empirical evidence (Chen and Dahlman, 2004; Gould and Gruben, 1996) supports the idea that strong patent protection is associated to higher economic growth. Chen and Dahlman (2004) find that a 20 percent increase in the annual number of patents held is associated with an increase of 3.8 percentage points in annual economic growth.

Another way to assess the impact of patents on employment is to evaluate the creation of new businesses based on patented inventions. Many start-ups in industries like biotechnology, semiconductors, instruments and chemicals have used their intellectual property as a means of obtaining financing and corporate partners, both of which are critical for the successful commercialisation of new knowledge.

Sometimes patents are crucial for such firms to arise. This is because without them these firms cannot appropriate the returns from their innovations unless they carry out further downstream steps in the innovation process, like developing the innovations or producing and selling the final goods. But if they do not have the resources and the capabilities to invest in such downstream assets, most often they do not produce the invention in the first place. By contrast, intellectual property enables them to sell the rights on the invention to other firms that own development and commercialisation assets. This encourages the formation of these firms, and the market for technology discussed earlier.

Studies on this topic include the empirical analysis on the spin-offs from patented inventions by university scientists of Shane (2004) and Shane and Khurana (2003), the study on large firms of Klepper (2001), and the study on venture capital backed spin-offs of Gompers, Lerner, and Sharfstein (2004). However, systematic evidence on the formation of new firms from patented inventions is still missing.

Ziedonis (2003) reports that, since the 1980's there was rapid entry in the semiconductor industry by design firms that relied heavily on patents to protect their intellectual property. According to Ziedonis (2003), from their first appearance in 1983, the number of semiconductor design firms grew to over 40 by 1994, which suggests that in the very industry where concerns have been raised over the effect of patent portfolio races and cross-licensing on entry, we observe entry based at least partly on the strength of patent protection (Cohen, 2004). There is also consensus that in industries where patents are especially effective, they have provided the basis for raising capital and stimulating entry, as in biotechnology (e.g., Henderson, Orsenigo and Pisano, 1999).

Theme B2: The impact of patent protection on knowledge spillovers and productivity

To what extent the reduced social value of the inventions produced by the protection offered by the patent is compensated by the fact that patents enhance social welfare by encouraging knowledge spillovers?

Theoretical models have shown that knowledge spillovers are an important determinant of economic growth. For example, they reduce the need for duplicate investments in R&D, and this provides opportunities for real cost reductions and increases in total factor productivity. Yet, empirically it is hard to measure spillovers, as well as to identify their beneficiaries and their sources. Even more challenging is to evaluate the impact of patents in facilitating these flows, as demonstrated by the limited amount of studies which have attempted to do so.

There is a well established literature using patent citations to assess whether different patent holders rely on each other knowledge bases. Jaffe, Trajtenberg and Henderson (1993) have used patent citations to assess the importance of spillovers across geographically close inventors. Similar studies have been carried out for Europe (Verspagen, 1997 and Verspagen and De Loo, 1999; Verspagen and Schoenmakers, 2004). One of the main results of this literature is that patent citations are higher the shorter the geographical distance between inventors of the cited and citing patents, supporting the idea that knowledge flows are geographically concentrated. Similarly, using a panel data from the US and Japan, Branstetter (2001) provides estimates of the relative impact of intra-national and international knowledge spillovers on innovation and productivity at the firm level, suggesting that knowledge spillovers are primarily intra-national in scope.

Breschi and Lissoni (2001) suggest however that a large fraction of such patent-based spillovers are market mediated, and therefore are not 'true' externalities. Convincing survey evidence on the validity of patent citations as a measure of spillovers is provided by Jaffe, Trajtenberg and Fogarty (2000), which confirm that patent citations reflect spillovers as perceived by the participants, albeit with substantial noise. Jaffe, Fogarty and Banks (1998) find that two-thirds of citations to patents of NASA-Lewis' Electro-Physics Branch were evaluated as involving spillovers.

Other recent studies on this topic reinforce the limit of patents as channels of information flows. By analysing the US semiconductor industry, Almeida and Kogut (1999) find that knowledge flows are embedded in regional labour networks, implying that patents are important, but not sufficient for transferring knowledge across firms. This has been recently confirmed by Singh (2005), using patent citations for a large sample of US multinational firms. Similarly, Breschi and Lissoni (2005) provide evidence that geography is not a sufficient condition for accessing a local pool of knowledge, but it requires active participation in a network of knowledge exchanges, for a sample of Italian firms belonging to multiple industries. For a recent methodological survey on how to identify and measure research spillovers see Garcia Fontes (2005).

A problem which permeates the studies of spillovers that use patent citations is related to the fact that a larger number of citations may also capture greater technological activity in a particular field, and thus greater competition. Once one recognizes this dual role of spillovers in general, it is not obvious what their impact on industry R&D is. This issue is at the core of the indirect effects of patents, and it has not been adequately explored in the existing empirical literature.

A second major problem for the use of citations as indicator of spillovers has been recently discussed by Alcacer and Gittelman (2004), who exploit recently available data for the US suggesting that an important fraction of citations contained in a patent are included by the examiners. In particular, they show that in the US the examiners add 40 per cent of all citations and two-thirds of citations on the average patent are added by examiners. Furthermore, 40 per cent of all patents have all citations added by examiners.

A major source of information on the empirical importance of patents in facilitating knowledge diffusion has been survey evidence presented by Cohen et al. (2002), who suggest that patents play a more central role in diffusing information across rivals in Japan relative to the US manufacturing sector, and appear to be a key reason for greater intra-industry R&D spillovers there, suggesting that patent policy can importantly affect information flows. This is confirmed by Maskus and

McDaniel (1999), who provide econometric evidence that the technology diffused through the Japanese patent system had a significant and positive impact on post-war growth in Japanese total factor productivity.

Cross-section survey evidence on the use of patents as information channels in Europe is provided by Arundel and Steinmueller (1998). They show that the probability of using patent databases increases with firm size and R&D investments, and it is higher among firms that also find patents as a valuable appropriation mechanism. They also find that across industries, a greater propensity to patent is positively associated with a greater use of patents as a channel of information on other firms' innovative activities.

In general, however, very few studies have been able to assess the extent to which knowledge spillovers are conditioned by patent protection, and the causal link between such flows and firms' R&D productivity. This is true for both the US and Europe.

3. DESCRIPTIVE STATISTICS II: PATVAL DATASET

3.1 The Patval Dataset

This Section uses the Patval-EU database to present Tables of descriptive statistics on the value of European patents, their economic use, the motives for patenting, the importance of patents for setting up new firms, and the extent of knowledge spillovers that arise from different sources during the innovation process. We provide these statistics by country, technology and type of applicants' organization.

The Patval-EU dataset was constructed by collecting information from the inventors of European patents applied at the EPO in 1993-1997.[2] The full scale PatVal-EU survey was conducted from May 2003 to January 2004, and it was directed to the inventors of 27,531 EPO patents with priority date in 1993-1997 located in France, Germany, Italy, the Netherlands, Spain and the United Kingdom (hereafter, "EU6 countries"). The targeted number of patents for which we expected the inventors to respond was 10,000. In the end the European inventors responded to 9,624 questionnaires covering 9,017 patents[3].

The distribution of the surveyed patents across countries is the following: 3,346 patents are invented in Germany, 1,486 in France, 1,542 in the UK, 1,250 in Italy, 1,124 in the Netherlands, and 269 in Spain. The number of patents surveyed in each country mirrors the relative size of the country population.

The PatVal-EU survey covers representative samples of patents in the following technological areas: Biotechnology, Pharmaceutical, Chemicals, Computing, Electronics (including Semiconductors), Communications, Electrical engineering, Mechanical engineering, Production engineering, Instruments. The survey provides also information about the type of the patent applicant: it indicates if the applicant is a small firm (less than 100 employees), a medium-seized firm (100-250), a large firm (<250), a university, a public or private research institution, or an individual inventor. The composition of the sample by technological classes and types of inventors' employers is reported in Tables A2-A3 in Annex III.

The primary goal of the PatVal-EU survey was to gather information on the economic value of the European patents. The PatVal-EU survey, however, produced other interesting and unique data on: *the characteristics of the inventors,* like their age, the educational and work background, the institutions to which they are affiliated; *the process that led to the innovation* such as the sources of knowledge used in the research process, and the setting up of formal or informal collaborations

[2] The dataset was built within the PatVal-EU project of the European Commission (contract number HPV2-CT-2001-00013).

[3] The number of observations in the Tables and Figures presented in this Report may be lower than 9017, and they may differ across Tables and Figures. This is because the extent to which the variables used in this Report suffer from missing observations differs.

among individual inventors and organisations; *the motivations to patent and the use of property rights*, such as the licensing behaviour of firms, the strategic reasons to patent, etc. The combination of this information provides a good understanding of the relationship between the input and the output variables in the innovation process, and it helps derive policy implications for the European innovative and economic performance[4].

In the present context the PatVal-EU survey gives the opportunity to investigate a number of issues related to the value of patents and their economic exploitation that the literature has partially neglected because of the lack of suitable information that the patent documents alone could not provide. Specifically, this Section provides a number of Tables and descriptive statistics to analyse the 4 themes of our study:

- A1. The Value and Social Costs of Patents. We use the PatVal-EU data on whether the patent produced economic returns. We employ the inventors' estimate of the monetary value of the patents, the number of forward citations they receive after the publication date, and whether the patent gave rise to opposition procedures in Courts. We also use the inventors' estimate of the man months required by the research activity leading to the patents.

- A2. The Economic Use of Patents. We employ data on whether the patent right was used for commercial or industrial purposes, or if it was licensed. We also use information about the strategic motives for patenting, such as the reaction to the behaviour of rivals or the willingness to block competitors.

- B1. The creation of new firms from the patented innovation. We use data on whether the patent gave rise to a new firm.

- B2. Collaboration, Spillovers and the Sources of Knowledge in the Innovation Process. We gathered information on the existence of any form of collaboration among the inventors who developed a patent, and we explored whether the inventors are employed in the same organisation or in different organizations. We also employ data on whether the research leading to the patent was based on formal and informal collaborations among different institutions, and we checked for the importance of the geographical distance among the parties involved in the exchange of knowledge.

3.2 The Value and Social Costs of Patents

The value of patents

There is a long literature on the impact of patents on innovative and economic competitiveness. This literature describes the positive effects of patents that might offset some of the social costs of

[4] For detailed information on the methodology adopted for the PatVal-EU survey and for descriptive statistics of the main variables see the PatVal-EU final report (European Commission, 2005).

intellectual property protection. This Section focuses on the monetary value of European patents, which is typically estimated in the literature by using indirect measures. As the review of the literature pointed out, these indicators include, for example, the number of citations that patents receive after their publication (Trajtenberg, 1990; for a survey see Hall *et al,* 2001), the renewal fees paid by the patent holders to extend the patent protection (Pakes and Schankerman, 1984; Pakes, 1986; Schankerman and Pakes, 1986), the number of backward citations to other patents and to the non-patent literature (Harhoff *et al.,* 1999), the number of countries in which the patent is asked for protection, and the number of opposition and annulment procedures incurred by the patents (Harhoff and Reitzig, 2004). Multiple measures are also employed to construct composite indicators of the quality of patents (Lanjouw and Schankerman, 2004). Although these indirect measures are useful when the actual monetary value of the innovations cannot be observed directly, they have a number of limitations (Griliches, 1988).

Very few studies use survey-based information on the economic value of patents in specific countries (Harhoff *et al.*, 1999a, 1999b, 2003; Scherer and Harhoff, 2000). Our PatVal-EU survey provides new data on the monetary value of patents, and its determinants. To obtain a measure of the present value of the patent we asked inventors to give their best estimate of the value of the innovations that they contribute to develop. More precisely, inventors were asked to estimate the minimum price at which the owner of the patent, whether the firm, other organisations, or the inventor himself, would have sold the patent rights on the very day in which the patent was granted. To improve the precision of this "best estimate" we asked the inventor to assume that he/she had all the information available at the moment in which responded to the questionnaire.[5] This Section reports the patents' monetary value obtained through the PatVal-EU survey. The Tables below show the distribution of the value of European patents by country, technological class, and type of organisation in which the inventors were employed at the time of the invention.

Figure 3.1 shows the value of the PatVal-EU patents in each of the six European countries involved in the survey. We constructed 10 classes for the value of the patents, ranging from those that are worth less than 30 thousands Euros, up to patents that are estimated to produce more than 300 million Euros. Consistently with the well-known skewness of the distribution of the patent value (i.e. only few patents produce high economic returns, Harhoff *et al.* 1999a, 2003, and Scherer and Harhoff 2000) only 7.2 % of the patents in our sample are worth more than 10 million Euros, and 16.8 % have a value higher than 3 million Euros. A share of 15.4% has a value between 1 and 3 million Euros. However, the largest share of patents falls in the left-end of the distribution. About

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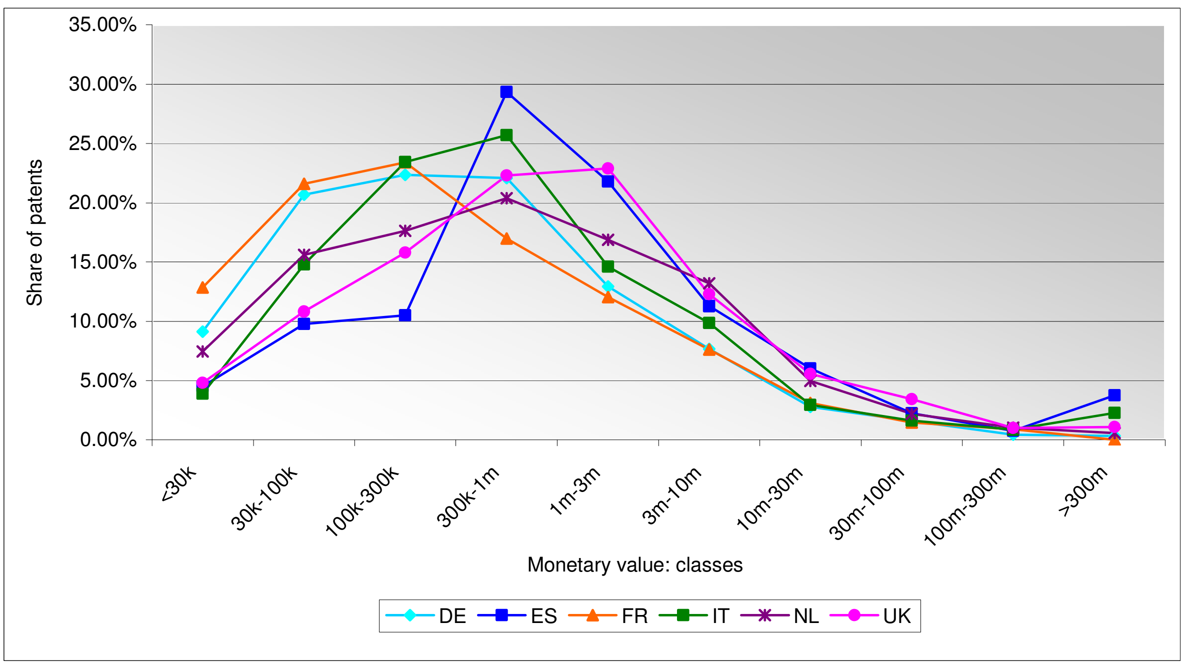
[5] There could be differences in the amount of information available to the inventors about the patent value. In particular, the inventors might have less information for more recent patents. However, the questionnaire was answered in 2003-2004, which is 6-7 years after the application year of the latest patents in the survey (1997). This is a sufficient time span for a good deal of information about the use and value of the patents to become available. Another concern we had is that the inventors may not be the most informed respondents about the value of the patents. A manager, especially in the case of large firms would be a more suitable person to ask. Since we were aware of this problem, we monitored whether the inventors actually knew about the value of their invention (for details and for the tests we performed on this issue, see European Commission, 2005).

68% of all our patents produce less than 1 million Euros, and about 8 % have a value lower than 30 thousand Euros.[6]

At the country level, Spain, the Netherlands and the UK have a share of high value patents larger than the EU6 share. The share of patents with a value higher than 10 million Euros is 12.79% in Spain, 8.86% in the Netherlands and 11.12% in the UK. Italy follows with 7.68%. Germany and France are in the bottom of the list with 5.19% and 5.58 % of patents with a value higher than 10 million Euros. Symmetrically, the share of patents whose value is lower than 1 million Euros is lower in Spain (54.13%), the UK (53.73%) and the Netherlands (61.04 %) compared to the EU6 share (67.8%). Italy comes fourth with 67.83%, while Germany (74.95%) and France (74.9%) have the largest share of comparatively lower value patents.

Table 3.1 reports the average monetary value of the patents invented in each country along with the standard deviations. The value of each patent in the sample is approximated by the mean value of the monetary class in which it falls. Consistently with Figure 3.1, the average monetary value of the patents is higher in Spain, Italy, the Netherlands, and the UK compared to the average EU6 value.

Figure 3.1 The value of European patents across the EU countries



[6] Some statistics presented in this report might slightly differ from those presented in the PatVal-EU report. This is due to the additional data cleaning and coverage of missing observations that we performed after we delivered the final PatVal-EU report to the European Commission.

Table 3.1 The value of European patents across the EU countries

	DE	ES	FR	IT	NL	UK	Total
Average patent value	4,008 (21,397)	16,049 (58,610)	3,640 (16,318)	10,675 (47,000)	6,767 (28,629)	9,210 (36,010)	6,358 (30,407)
Average number of forward citations	1.63 (2.46)	0.33 (1.02)	0.63 (1.20)	0.89 (1.22)	0.27 (0.97)	0.20 (0.64)	0.91 (1.80)
Share of opposed patents	9.98%	4.49%	11.71%	10.10%	6.49%	3.63%	8.60%
Number of observations	3,346	267	1,486	1,248	1,124	1,542	9,013

Note: standard deviations in parenthesis. The number of observations shown in this Table refers to the number of forward citations and opposed patents. For the average patent value the number of observation is 7,754.

Table 3.1 also shows the share of patents that have incurred in opposition procedures, and the average number of citations received by the patents after their publication (i.e. forward citations). The average number of citations received by the patents after their publication date is particularly high for patents invented in Germany where they receive 1.63 citations on average compared to 0.91 of the EU6 average. This is probably due to the presence of large companies in Germany that because of their large patent portfolios tend to cite their own patents more than smaller companies. Italy and France follow with an average of 0.89 and 0.63 citations per patent. Also the share of opposed patents is higher in Germany, France and Italy compared to the other countries and to the EU6 share.

We also collected information on the address of the inventors of our PatVal-EU patents, and we used it to assign each innovation to the European region in which it was invented. The geographical classification used for this exercise is the *Nomenclature des Unités Territoriales Statistiques* at the second level of disaggregation (NUTS2) as provided by Eurostat.[7]

Table 3.2 lists the European regions whose patents have an average monetary value higher than the overall EU6 average. It also reports the average number of forward citations and the percentage of patents that incurred in litigation procedures. Table A.6 in Annex AIII.1 complements Table 3.2 by showing the average monetary value, citations and oppositions for the regions with an average patent value below the EU6 average. The average value of patents is highest for a group of regions in UK (i.e. Kent, Outer London, Surrey and Sussex, Leicestershire, Rutland and Northants, Cheshire) and for a group of Italian regions (Toscana, Friuli-Venezia Giulia, Piemonte e Lombardia). Cataluña in Spain is the third region in this rank. Germany and the Netherlands are listed with a few regions in the lower part of the ranking, while France appears with only one region with an average patent value above the overall EU6 average. For some of these regions the average number of forward citations and the share of opposed patents is also above the average, but when we perform specific tests on the ranking correlation between the three indicators, the results are inconclusive. This is so both at the country level and at the NUTS2 level. The research in the second part of this project (i.e. Lot2) will specifically look at the correlation between different indicators of the patent value by using multiple correlation analysis that controls for many other

[7] We calculated the statistics at the regional level only for the NUTS2 regions in which 30 or more patents of our sample were invented. The *Nomenclature des Unités Territoriales Statistiques* (NUTS) is a Eurostat classification that subdivides the European Union in groups of regions (NUTS1), regions (NUTS2) and provinces (NUTS3).

factors that potentially affect the value of the European patents, such as the characteristics and the education of the inventors, the company specificities and the technological classes in which the patents were invented.

Table 3.2 The value of European patents across European regions (NUTS2)

Country	NUTS 2	Average value (st dev)	Average Forward Cits (st dev)	% Opposed patents	Number of obs.
UK	Kent	25829.89 (76980.73)	0.16 (0.47)	4.08%	49
IT	Toscana	19727.24 (72344.04)	0.49 (0.73)	15.79%	57
ES	Cataluña	14616.73 (56739.45)	0.28 (0.89)	3.45%	116
UK	Outer London	14573.65 (37321.74)	0.25 (0.81)	2.27%	44
UK	Surrey, east and west Sussex	14197.86 (51231.71)	0.38 (1.02)	1.08%	93
UK	Leicestershire, Rutland and Northants	13263.47 (50512.11)	0.08 (0.36)	2.70%	37
UK	Cheshire	12772.23 (48821.03)	0.06 (0.23)	1.89%	53
IT	Friuli-Venezia Giulia	12445.22 (52056.64)	1.12 (1.49)	22.37%	76
IT	Piemonte	12037.34 (52226.49)	1.03 (1.30)	7.80%	205
IT	Lombardia	11779.89 (49308.31)	0.83 (1.08)	9.67%	424
UK	Bedfordshire, Hertfordshire	11660.59 (51165.69)	0.09 (0.29)	0.00%	44
UK	Eastern Scotland	10720.47 (52816.81)	0.21 (0.48)	3.03%	33
UK	Berkshire, Bucks and Oxfordshire	10641.89 (43238.59)	0.24 (0.70)	5.51%	127
DE	Gießen	10391.89 (49158.99)	1.65 (1.69)	8.11%	37
DE	Rheinhessen-Pfalz	10336.77 (34892.21)	2.05 (3.93)	10.31%	194
NL	Noord-brabant	9070.42 (38528.17)	0.35 (1.40)	5.64%	337
DE	Karlsruhe	8886.02 (44760.44)	1.66 (2.95)	12.24%	147
UK	Derbyshire and Nottinghamshire	8556.59 (18498.85)	0.33 (0.84)	0.00%	46
UK	West Yorkshire	8313.45 (40003.26)	0.18 (0.53)	3.23%	62
DE	Freiburg	8016.79 (37445.50)	1.56 (2.09)	3.33%	90
DE	Hannover	7077.53 (35023.46)	1.42 (1.90)	6.82%	88
NL	Limburg	7002.59 (22431.97)	0.35 (0.82)	7.89%	114
FR	Provence-alpes-Côte d'azur	6751.56 (23305.98)	0.45 (1.05)	8.62%	58
UK	West Wales and the valleys	6369.49 (21434.06)	0.24 (0.51)	0.00%	51
Total		6358.35 (30407.00)	0.91 (1.80)	8.60%	9013

Note: the number of observations reported in the Table refers to the patents we used to calculate the average number of forward citations and oppositions. For the average patent value the number of observations is 7,754.
This Table shows the European regions in which the average value of patents is above the EU6 average, and the number of observations in each region is ≥30.

We classified our sample patents in five "macro" technological classes: Electrical Engineering, Instruments, Chemicals-Pharmaceuticals, Process Engineering, and Mechanical Engineering.[8] Table 3.3 shows the distribution of the patent value in these five macro-technologies. Innovations that are worth more than 10 million Euros are more frequent in Chemicals and Pharmaceuticals (11.71%) compared to the overall sample (7.23%). Process Engineering comes second with a share of 6.75% patents that are worth more than 10 million Euros, just below the EU6 average. The share of top-value patents is 6.22% in Electrical Engineering, 6.10% in Mechanical Engineering and 5.60% in

[8] The technological classification uses the framework elaborated by the German Fraunhofer Institute of Systems and Innovation Research (ISI) together with the French patent office (INIPI) and the Observatoire des Science and des Techniques (OST). This classification is based on the International Patent Classification (IPC) and distinguishes among 30 "micro" technological fields and 5 "macro" aggregated technological areas. The correspondence between the "macro" and "micro" technological classes is reported in Table A1 in Annex III.

Instruments. Symmetrically, 58.00% of the Chemical and Pharmaceutical patents are in the left-end tail of the distribution where patents generate less than 1 million Euros. Electrical Engineering, Instruments, Process Engineering and Mechanical Engineering have a share of about 70% of patents with a value lower than 1 million Euros (72.65%, 68.74%, 67.92% and 70.36% respectively).

These data are mirrored in the average monetary value of the patents. The average value of a Chemical-Pharmaceutical patent is much higher than the average value of a patent in any other technological class. This is so also for the average number of forward citations (1.04 compared to 0.91 of the overall EU6 average). Differently, the share of opposed patents is the highest in Process Engineering (11.57%). Chemicals-Pharmaceuticals follows with 8.99% of opposed patents, and Mechanical Engineering is third with a share of 10.62% of patents that incurred in opposition procedures. Electrical Engineering and Instruments are at the bottom of the list with 5.68% and 6.73% of opposed patents.

Table 3.3 The value of European patents by "macro" technological class

Value intervals	Electrical Engineering	Instruments	Chemicals & Pharmaceuticals	Process Engineering	Mechanical Engineering	Total
<30k	9.61%	8.91%	6.36%	6.38%	8.78%	7.88%
30k-100k	18.14%	18.41%	12.93%	18.69%	18.21%	17.39%
100k-300k	22.70%	20.55%	17.00%	20.58%	21.88%	20.65%
300k-1m	22.20%	21.14%	21.71%	22.27%	21.49%	21.80%
1m-3m	14.08%	14.85%	18.64%	15.93%	14.07%	15.45%
3m-10m	7.04%	10.57%	11.64%	9.40%	9.47%	9.58%
10m-30m	3.40%	3.33%	5.93%	3.68%	2.69%	3.70%
30m-100m	1.66%	1.31%	3.43%	1.74%	1.79%	2.00%
100m-300m	0.75%	0.48%	1.21%	0.61%	0.72%	0.76%
>300m	0.41%	0.48%	1.14%	0.72%	0.90%	0.77%
Total	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
Average patent value	4,809 (24,474)	4,578 (24,119)	9,581 (37,075)	5,784 (28,886)	6,354 (31,863)	6,359 (30,410)
Average number of forward citations	0.84 (1.69)	0.87 (1.82)	1.04 (2.34)	0.94 (1.75)	0.86 (1.48)	0.91 (1.80)
Share of opposed patents	5.68%	6.73%	8.99%	11.57%	8.10%	8.60%
Number of observations	1,425	981	1,669	2,248	2,690	9,013

Note: standard deviations in parenthesis. The number of observations shown in this Table refers to the number of forward citations and opposed patents. For the average patent value the number of observation is 7,752.

Table 3.4 shows the technological classification of our patents in 30 "micro" technological classes, and reports the distribution of the patent value in each class. Again, there are technologies in which the probability of inventing valuable patents is higher than in others. If we consider the innovations that are worth more than 10 million Euros, the technological sectors with the highest share of patents in this class are: Pharmaceuticals & Cosmetics (17.48%), Semiconductors (12.81%), Organic Fine Chemistry (13.07%), Chemical, Petrol & Basic Material Chemistry (12.54%), and Material Processing, Textile & Paper (9.90%). Consistently, with Table 3.3 other two chemical technologies (Agriculture & Food Chemistry, Macromolecular Chemistry & Polymers) are in the top positions. Unexpectedly, biotechnology stands in the lower ranking: the share of patents that are worth more than 10 million Euros is 3.5%, below the overall European average (7.23%). In Biotechnology, however, there is a large share of patents with a value between 1 and 10 millions Euros (about 29.83%). As far as the left-end tail of the distribution is concerned (i.e. patents that generate less than 1 million Euros) the share of patents in this class is high in Consumer Goods and Equipment (76.06%), Electrical Devices (75.21%), Agricultural Machinery and Processing (74.69%). The lowest shares of low value patents are in Pharmaceuticals and Cosmetics, Organic Fine Chemistry, Materials and Metallurgy, and Agriculture & Food Chemistry.

Table 3.5 shows the average monetary value of the PatVal-EU patents in the 30 "micro" technological classes. Patents in Organic Fine Chemistry, Pharmaceuticals & Cosmetics, Semiconductors, Material Processing, Textile & Paper, and Petrol & Basic Material Chemistry are ranked in the top positions. Compared to the European overall share of patents that incurs in opposition procedures (8.60%), Table 3.5 shows that the share of opposed patents is larger in Materials and Metallurgy (16.56%), Material Processing, Textile & Paper (13.35%), Macromolecular Chemistry & Polymers (13.17%), Agricultural & Food Processing (12.87%) and Surface Technology and Coating (11.67%). Semiconductors are at the bottom of the list with only 1.16% patents being opposed (i.e. one patent). The low share of opposed patents in Semiconductors might be explained by the frequent use of cross-licensing agreements among the large semiconductor firms. By means of cross-licensing these firms share their patent portfolios and avoid costly litigations. Semiconductors are also the top sector in terms of the average number of forward citations (1.38 compared to 0.89 of the overall European average). Macromolecular Chemistry and Polymers follow with 1.33 forward citations on average. Biotechnology patents receive the lowest average number of citations (0.23). This might depend on the fact that citations include also self-citations, i.e. citations made by patents developed by the very same company that applied for the cited patent. Compared to smaller firms in biotechnology, large chemical and semiconductor companies have larger patent portfolios that can cite their own patents.

Table 3.4 The value of European patents by "micro" technological class, in %

ISI Technological Classes	<30k	30k-100k	100k-300k	300k-1m	1m-3m	3m-10m	10m-30m	30m-100m	100m-300m	>300m	Total
Electrical Devices, Electrical Eng. & Electrical Energy	9.95	19.02	24.08	22.16	13.61	6.81	2.97	0.87	0.17	0.35	100.00
Audio-visual Technology	6.00	21.33	20.00	24.00	16.00	5.33	3.33	0.67	2.67	0.67	100.00
Telecommunications	12.07	14.22	24.57	19.40	12.07	9.48	3.88	3.45	0.86	0.00	100.00
Information Technology	8.05	21.26	16.09	24.71	17.24	6.90	2.30	2.30	1.15	0.00	100.00
Semiconductors	10.26	10.26	26.92	21.79	12.82	5.13	7.69	2.56	0.00	2.56	100.00
Optics	11.51	13.67	17.99	17.99	18.71	12.23	4.32	2.88	0.00	0.72	100.00
Analysis, Measurement, & Control Technology	8.89	21.26	22.13	18.66	14.32	10.20	2.60	0.87	0.65	0.43	100.00
Medical Technology	7.21	14.42	19.71	28.85	13.46	9.62	4.33	1.44	0.48	0.48	100.00
Organic Fine Chemistry	7.88	11.94	14.86	22.75	17.12	12.39	5.41	3.83	2.03	1.80	100.00
Macromolecular Chemistry & Polymers	5.49	13.47	19.45	22.94	19.95	9.48	5.74	2.49	0.25	0.75	100.00
Pharmaceuticals & Cosmetics	6.29	15.38	16.78	16.78	16.78	10.49	9.79	5.59	0.00	2.10	100.00
Biotechnology	3.51	22.81	22.81	17.54	10.53	19.30	1.75	0.00	0.00	1.75	100.00
Materials & Metallurgy	5.70	12.93	20.53	19.77	19.77	12.93	3.80	3.80	0.76	0.00	100.00
Agriculture, & Food Chemistry	5.43	10.87	18.48	26.09	18.48	10.87	4.35	4.35	0.00	1.09	100.00
Chemical & Petrol Industry, Basic Materials Chemistry	6.08	11.03	15.21	20.15	22.05	12.93	6.46	3.42	2.66	0.00	100.00
Chemical Engineering	5.45	18.68	19.07	21.01	17.90	11.28	4.28	1.56	0.39	0.39	100.00
Surface Technology & Coating	5.69	17.89	24.39	25.20	13.82	4.07	4.88	1.63	1.63	0.81	100.00
Materials Processing, Textiles & Paper	4.84	15.21	18.20	28.34	15.44	8.06	5.76	1.61	0.92	1.61	100.00
Thermal Processes & Apparatus	9.25	17.92	20.23	19.08	15.03	10.40	4.05	1.16	1.73	1.16	100.00
Environmental Technology	6.56	16.39	25.41	15.57	18.03	14.75	1.64	0.82	0.00	0.82	100.00
Machine Tools	11.68	14.60	21.53	21.90	12.77	10.22	2.55	2.92	0.36	1.46	100.00
Engines, Pumps & Turbines	7.73	14.55	21.36	16.36	20.00	11.82	2.73	3.64	0.91	0.91	100.00
Mechanical Elements	9.60	20.62	18.36	24.29	12.99	11.30	0.28	1.41	0.28	0.85	100.00
Handling & Printing	7.76	21.75	21.25	21.59	14.50	7.93	2.70	1.52	0.51	0.51	100.00
Agricultural & Food Processing, Machinery & Apparatus	8.43	28.31	20.48	17.47	13.25	9.64	1.20	0.60	0.00	0.60	100.00
Transport	9.59	16.42	21.77	21.96	13.65	9.23	4.24	1.85	0.74	0.55	100.00
Nuclear Engineering	8.82	23.53	14.71	20.59	14.71	14.71	2.94	0.00	0.00	0.00	100.00
Space Technology Weapons	4.17	16.67	20.83	27.08	12.50	10.42	6.25	2.08	0.00	0.00	100.00
Consumer Goods & Equipment	7.05	22.92	26.95	19.14	11.84	6.80	1.76	1.76	1.01	0.76	100.00
Civil Eng., Building & Mining	7.42	18.69	21.36	24.04	15.43	8.31	2.67	0.30	0.59	1.19	100.00
Total	7.88	17.39	20.65	21.80	15.45	9.58	3.70	2.00	0.76	0.77	100.00

Table 3.5 The value of European patents: average value, share of opposed patents and average number of forward citations by "micro" technological class

ISI Technological Classes	Average value (st dev)	Average Forward Cits (St dev)	% Opposed patents	Number of obs.
Electrical Devices, Electrical Eng. & Electrical Energy	3,163 (19,771)	0.84 (1.67)	8.26%	678
Audio-visual Technology	7,722 (34,448)	0.81 (1.62)	3.41%	176
Telecommunications	5,090 (18,118)	0.80 (1.77)	4.20%	286
Information Technology	4,471 (18,610)	0.67 (1.72)	3.02%	199
Semiconductors	11,230 (48,371)	1.36 (1.64)	1.16%	86
Optics	5,908 (27,477)	0.95 (1.95)	5.33%	169
Analysis, Measurement, & Control Technology	4,280 (23,812)	0.79 (1.72)	6.89%	537
Medical Technology	4,806 (24,409)	1.09 (2.04)	8.15%	233
Organic Fine Chemistry	12,988 (45,754)	1.07 (2.52)	4.01%	549
Macromolecular Chemistry & Polymers	6,204 (28,562)	1.35 (2.17)	13.17%	463
Pharmaceuticals & Cosmetics	12,478 (44,830)	0.87 (1.75)	11.63%	172
Biotechnology	7,103 (39,603)	0.27 (0.76)	4.29%	70
Materials & Metallurgy	5,489 (17,815)	0.88 (1.50)	16.56%	308
Agriculture, & Food Chemistry	7,929 (33,559)	0.51 (1.42)	10.43%	115
Chemical & Petrol Industry, Basic Materials Chemistry	8,520 (26,345)	1.01 (2.93)	10.67%	300
Chemical Engineering	4,586 (22,345)	0.77 (1.52)	8.62%	290
Surface Technology & Coating	7,352 (33,683)	0.95 (1.88)	11.76%	136
Materials Processing, Textiles & Paper	9,112 (40,802)	0.98 (1.73)	13.35%	487
Thermal Processes & Apparatus	8,498 (37,808)	0.68 (0.98)	10.47%	191
Environmental Technology	4,619 (27,707)	1.11 (1.81)	11.72%	145
Machine Tools	8,251 (38,302)	0.87 (1.43)	11.36%	317
Engines, Pumps & Turbines	8,082 (33,583)	0.82 (1.52)	7.42%	256
Mechanical Elements	5,058 (29,473)	0.99 (1.59)	8.46%	390
Handling & Printing	4,589 (24,962)	0.98 (1.98)	8.82%	680
Agricultural & Food Processing, Machinery & Apparatus	3,370 (23,808)	0.91 (1.53)	12.87%	202
Transport	5,597 (26,945)	1.07 (1.73)	6.54%	627
Nuclear Engineering	1,791 (3,217)	0.45 (1.04)	2.38%	42
Space Technology Weapons	3,376 (9,875)	0.74 (1.22)	3.51%	57
Consumer Goods & Equipment	5,990 (30,903)	0.74 (1.25)	7.69%	468
Civil Eng., Building & Mining	6,019 (34,520)	0.66 (1.40)	8.07%	384
Total	6,360 (30,411)	0.91 (1.80)	8.60%	9013

Note: standard deviations in parenthesis. The number of observations shown in this Table refers to the number of forward citations and opposed patents. For the average patent value the number of observation is 7,752.

Table 3.6 lists different types of organisations in which the PatVal-EU inventors were employed at the time of the invention: large firms, medium-sized firms, small firms, private non-profit research institutions (like Foundations and Hospitals), public research organisations, universities, government laboratories, and other employers like the inventors themselves or other institutions. The Table reports the distribution of the patent value for each type of inventors' employer. The share of innovations that are worth more than 10 million Euros is higher for government laboratories (10.00%), private non-profit research institutions (9.25%), large companies (7.51%) and in the "other" residual category (10.00%) compared to the overall European share (7.22%). Public research organisations and universities develop the smallest shares of very high value patents

(4.68% and 4.23%). This ranking is mirrored in the average monetary value of the patents in the first raw of the bottom part of Table 3.6. The most valuable patents are developed by government laboratories and private non-profit research institutions, followed by large companies and the "other" residual category.[9]

Patents invented in government research institutions, universities, public research institutions and private non-profit research institutions have a lower probability of being opposed compared to the overall EU6 share of opposed patents, suggesting a lower social cost of patent protection. By contrast, patents invented in private companies, and especially in large companies, are opposed more than the European average. Inventors employed by private firms also invent highly cited patents. As expected, this is particularly matching for patents developed by large companies, as they have large citing patent portfolios.

Table 3.6 The distribution of the value of European patents by type of inventors' employer, in %

	Large companies	Medium sized companies	Small companies	Private Research Institutions	Public Research Institutions	Universities	Other Governm. Institutions	Others	Total
<30k	8.77	6.43	4.14	11.11	10.67	8.05	20.00	6.00	7.92
30k-100k	17.59	17.98	15.53	12.96	20.00	19.07	10.00	14.00	17.36
100k-300k	20.73	22.81	20.04	20.37	22.00	19.49	10.00	12.00	20.73
300k-1m	20.77	23.25	25.37	22.22	21.33	24.15	30.00	28.00	21.84
1m-3m	15.37	14.04	16.73	11.11	12.67	16.53	0.00	16.00	15.38
3m-10m	9.26	9.21	11.03	12.96	8.67	8.47	20.00	14.00	9.54
10m-30m	3.65	3.65	4.50	3.70	2.67	1.69	0.00	2.00	3.68
30m-100m	2.22	1.46	1.38	1.85	0.67	1.27	0.00	6.00	1.99
100m-300m	0.87	0.00	0.64	3.70	0.67	0.00	10.00	2.00	0.76
>300m	0.77	1.17	0.64	0.00	0.67	1.27	0.00	0.00	0.79
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Average patent value	6,615 (30,851)	6,015 (33,051)	5,641 (27,681)	8,511 (29,486)	4,775 (27,759)	5,894 (34,291)	16,523 (46,970)	8,561 (25,577)	6,402 (30,655)
Average number of forward citations	1.08 (1.99)	0.64 (1.30)	0.51 (1.12)	0.36 (0.92)	0.52 (1.41)	0.37 (0.94)	0.29 (0.61)	0.85 (1.73)	0.92 (1.81)
Share of opposed patents	9.35%	8.90%	7.10%	4.48%	5.52%	3.87%	0.00%	10.17%	8.70%
Number of observations	6217	775	1211	67	181	284	14	59	8808

Note: standard deviations in parenthesis. The number of observations shown in this Table refers to the number of forward citations and opposed patents. For the average patent value the number of observation is 7,587.

The cost of patents

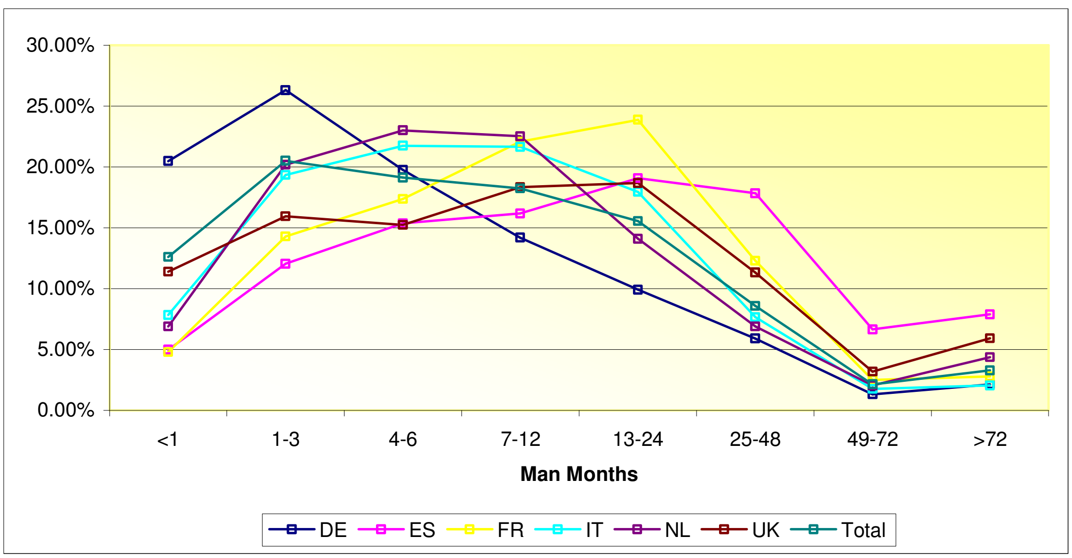
Consistently with the literature on the value and social costs of patents, the share of opposed patents is considered as an indicator of the value of patents (Harhoff and Reitzig, 2004). However, from a policy perspective, a system of strong intellectual property protection that leads to patent oppositions, also implies that the enforcement of property rights is costly, and that the social loss of

[9] However, government laboratories and private non-profit research institutions develop only 83 patents in our sample.

resources due to litigations in legal disputes is relevant (Cesaroni and Giuri, 2005). Furthermore, these costs are unevenly sustained by different actors (individuals vs. firms, large firms vs. small firms, firms with different characteristics). The Tables in the previous section showed that the share of opposed patents differs across countries, regions and technological classes, and that large and medium companies incur in patent suits more than small companies, private and public research institutions or individuals.

This section uses the amount of time devoted to the innovation process that leads to the patent as an indicator of its monetary cost. Precisely, we constructed 8 categories with the number of man-months required by the research project leading to the patent, ranging from 1 man-month (or less) up to more than 72 man-months. We analysed the length of the research process by country, "macro" and "micro" technological classes, and types of inventors' employer. Figure 3.2 shows that for the overall EU6 countries, 52.25% of the patents require up to 6 man-months for the invention process to be completed, while only 5.40 % of the patents require more than 48 man-months. At the country level, 66.56% of patents in Germany entails less than 6 man-months. In all the other countries the share of patents that takes more than 6 man-months to be invented is larger than in Germany. The large share of short research projects that lead to a patented invention suggests that there is a lot of patenting concerning "small" innovations that may actually be part of a group of intertwined patents developed within the same organisation.

Figure 3.2. The man-months required by the patents' invention process across countries



At the level of "macro" technological classes, Table 3.7 highlights interesting differences in the amount of resources requested by the invention process leading to the patent. In Chemical and Pharmaceutical technologies only 36% of the patents involve less up to 6 man-months for the invention process and 9.63% of patents involve more than 48 months (the overall EU6 shares are respectively 52.25% and 5.40%). By contrast, in Electrical Engineering and Mechanical Engineering the share of patents requiring less than 6 months is about 60% while the share of patents requiring more than 48 months are respectively 3.70% and 3.26%. The distribution of patents across categories in Instruments and Engineering are instead closer to the EU6 average.

Table 3.7 The man-months required by the patents' invention process by "macro" technological class

Man-months	Electrical Engineering	Instruments	Chemical & Pharmaceutical tech.	Process Engineering	Mechanical Engineering	Total
<1	15.48%	12.83%	3.00%	13.37%	16.57%	12.62%
1-3	24.02%	17.81%	13.88%	19.43%	24.78%	20.51%
4-6	20.09%	18.47%	19.13%	18.57%	19.31%	19.12%
7-12	17.67%	18.47%	21.25%	17.27%	17.26%	18.22%
13-24	13.37%	14.27%	20.19%	16.40%	13.52%	15.56%
25-48	5.66%	12.17%	12.94%	9.43%	5.31%	8.58%
49-72	1.28%	2.10%	3.69%	2.36%	1.37%	2.12%
>72	2.42%	3.87%	5.94%	3.17%	1.89%	3.28%
Total	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%

At the level of the 30 "micro" technological classes, Table 3.8 shows that the share of patents whose research process requires less than 6 man-months is larger than the EU6 average in Electrical Devices, Electrical Engineering & Electrical Energy (63.19%), Telecommunications (60.52%), Mechanical Elements (66.21%), Handling & Printing (65.56%), Transport (62.16%) and Civil Engineering, Building & Mining (63.27%). By contrast, the technological classes where a high share of patents requires more than 48 months for the invention process to be performed are Organic Fine Chemistry (12.45%), Pharmaceuticals & Cosmetics (10.18%), Biotechnology (12.31%), Materials & Metallurgy (11.72%), Agriculture & Food Chemistry (12.96%) and Environmental Technology (10.53%).

The distribution of patents across the 8 man-months categories and type of inventors' employer (Table 3.9) shows interesting differences among companies on the one hand, and research institutions and universities on the other hand. The number of man months required in the private sector to develop a patent (i.e. large, small and medium companies) is similar to the overall distribution. By contrast, in private and public research institutions, universities and other government organisations, the share of innovations produced in less than 6 man-months is sensibly lower than the EU6 average. It ranges from 25.71 to 35.71 %, while the share of patents that require more than 48 man-months is far above 5.25% of the EU6 average. It ranges between 11.04 and 21.43%. This suggests that, on average, the patents produced by research institutions and universities are the output of larger research projects compared to those invented in the private sector. Moreover, on average, the patents invented in small firms are skewed towards a large number of man-months required to develop them as compared to large firms' patents. This also suggests that "small" patents are less frequent in small firms, in which the legal costs of preparing and applying for a patent is often greater than in large firms.

Table 3.8 The man-months required by the patents' invention process by "micro" technological class

	<1	1-3	4-6	7-12	13-24	25-48	49-72	>72	Total
Electrical Devices, Electrical Eng. & Electrical Energy	17.06%	23.85%	22.27%	16.75%	13.11%	4.27%	1.26%	1.42%	100.00%
Audio-visual Technology	14.20%	25.31%	19.75%	24.07%	10.49%	3.70%	0.00%	2.47%	100.00%
Telecommunications	16.24%	26.94%	17.34%	15.50%	12.18%	7.01%	2.21%	2.58%	100.00%
Information Technology	12.15%	20.99%	18.23%	18.23%	13.81%	10.50%	1.10%	4.97%	100.00%
Semiconductors	10.39%	19.48%	16.88%	18.18%	24.68%	5.19%	1.30%	3.90%	100.00%
Optics	12.42%	20.50%	14.29%	19.25%	16.77%	11.18%	0.62%	4.97%	100.00%
Analysis, Measurement, & Control Technology	12.88%	17.38%	20.04%	18.81%	13.70%	12.27%	2.25%	2.66%	100.00%
Medical Technology	13.08%	17.29%	16.82%	16.36%	14.95%	12.62%	2.80%	6.07%	100.00%
Organic Fine Chemistry	1.92%	12.84%	17.05%	19.35%	20.69%	15.71%	2.49%	9.96%	100.00%
Macromolecular Chemistry & Polymers	1.55%	14.86%	21.29%	25.28%	19.07%	10.20%	4.21%	3.55%	100.00%
Pharmaceuticals & Cosmetics	4.19%	11.98%	15.57%	23.35%	21.56%	13.17%	5.99%	4.19%	100.00%
Biotechnology	3.08%	10.77%	20.00%	15.38%	20.00%	18.46%	3.08%	9.23%	100.00%
Materials & Metallurgy	5.17%	16.21%	16.55%	16.55%	18.97%	14.83%	4.14%	7.59%	100.00%
Agriculture, & Food Chemistry	5.56%	10.19%	18.52%	20.37%	15.74%	16.67%	5.56%	7.41%	100.00%
Chemical & Petrol Industry, Basic Materials Chemistry	5.57%	17.42%	21.60%	18.82%	21.95%	9.41%	3.14%	2.09%	100.00%
Chemical Engineering	12.69%	16.04%	18.66%	22.01%	15.67%	7.46%	4.48%	2.99%	100.00%
Surface Technology & Coating	7.09%	14.17%	19.69%	16.54%	22.83%	14.17%	1.57%	3.94%	100.00%
Materials Processing, Textiles & Paper	12.25%	18.04%	17.59%	18.49%	20.04%	9.35%	1.78%	2.45%	100.00%
Thermal Processes & Apparatus	14.86%	21.14%	20.00%	18.86%	12.57%	9.14%	0.57%	2.86%	100.00%
Environmental Technology	15.79%	13.53%	16.54%	12.78%	18.05%	12.78%	4.51%	6.02%	100.00%
Machine Tools	14.38%	24.66%	18.84%	18.84%	13.70%	6.85%	0.68%	2.05%	100.00%
Engines, Pumps & Turbines	21.85%	22.27%	14.71%	18.49%	12.18%	5.46%	2.10%	2.94%	100.00%
Mechanical Elements	20.33%	27.20%	18.68%	12.91%	14.01%	4.40%	1.10%	1.37%	100.00%
Handling & Printing	18.89%	26.03%	20.63%	15.71%	10.95%	6.03%	1.27%	0.48%	100.00%
Agricultural & Food Processing, Machinery & Apparatus	13.74%	18.13%	17.58%	17.58%	17.58%	9.89%	0.55%	4.95%	100.00%
Transport	19.01%	24.14%	19.01%	15.75%	12.84%	6.34%	1.54%	1.37%	100.00%
Nuclear Engineering	12.50%	15.00%	25.00%	22.50%	7.50%	12.50%	2.50%	2.50%	100.00%
Space Technology Weapons	7.14%	10.71%	26.79%	25.00%	21.43%	7.14%	1.79%	0.00%	100.00%
Consumer Goods & Equipment	12.21%	25.81%	20.74%	20.51%	13.13%	4.15%	1.61%	1.84%	100.00%
Civil Eng., Building & Mining	14.58%	27.99%	20.70%	16.03%	14.58%	2.33%	1.46%	2.33%	100.00%
Total	12.62%	20.51%	19.12%	18.22%	15.56%	8.58%	2.12%	3.28%	100.00%

Table 3.9 The man-months required by the patents' invention process by type of inventors' employer

	Large companies	Medium sized companies	Small companies	Private Research Institutions	Public Research Institutions	Universities	Other Governm. Institutions	Others	Total
<1	13.49%	11.50%	12.22%	4.92%	6.13%	5.95%	14.29%	8.93%	12.67%
1-3	22.54%	20.90%	14.61%	9.84%	11.66%	8.92%	21.43%	19.64%	20.57%
4-6	19.08%	22.16%	20.40%	14.75%	10.43%	12.64%	0.00%	23.21%	19.10%
7-12	17.61%	21.74%	19.49%	19.67%	18.40%	14.50%	14.29%	17.86%	18.14%
13-24	15.13%	14.45%	17.83%	9.84%	17.79%	21.56%	14.29%	16.07%	15.65%
25-48	7.48%	5.75%	10.39%	22.95%	24.54%	17.84%	14.29%	5.36%	8.50%
49-72	1.75%	1.82%	2.11%	1.64%	6.13%	8.18%	0.00%	1.79%	2.10%
>72	2.91%	1.68%	2.94%	16.39%	4.91%	10.41%	21.43%	7.14%	3.25%
Total	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%

Annex A III.1 adds five tables of descriptive statistics on the value and costs of patents. They describe the distribution of patent value, the average number of forward citations and oppositions, and the number man-months required for developing the innovations according to the number and type of countries in which the applicant organisations are located.

3.3 The Economic Use of Patents

The literature on the economic use of patents suggests that large firms tend to under-use their patents for strategic reasons. Licensing and the development of markets for technology are means to enhance the exploitation of patents (Arora, Fosfuri and Gambardella, 2001; Rivette and Kline, 2000; Hall and Ziedonis, 2001). The empirical work on these topics, however, is limited. There are contributions on the extent and motivations for licensing in specific industries, firms, and on the licensing activity of universities (Arora and Ceccagnoli, 2005; Gans et al, 2002; Nakamura and Odagiri, 2003). Cohen et. al (2000) use US firm data to show the motivations for patenting by US companies. Only a few studies analyse these issues more broadly by using US and Japanese data. In general, information on the actual use of patents is not available, and the evidence on whether patents are used internally by the applicant company for economic purposes or for strategic reasons, or if the patents are simply "sleeping" within the companies, is very poor. This is particularly true for the work done on European patents and firms.

By providing the necessary information on these issues, the PatVal-EU survey provides a unique opportunity to explore the different uses of European patents, and the motivations for patenting. This is the aim of the present Section that presents data by EU country, technological classes, and type of applicant organisations.

The use of patents

The PatVal-EU questionnaire defines six possible uses of patents:

- Internal use. The patent is exploited internally for commercial or industrial purposes. It can be used in the production processes or it is incorporated in marketed products. Likely, inventors and applicant organisations that use the patent internally have the downstream complementary assets to perform production and commercialisation activities.

- Licensing. The patent is not used internally by the applicant, but it is licensed out to another party.
- Cross-licensing. The patent is licensed to another party in exchange for another innovation.
- Licensing & use. The patent is both licensed out to another party, and it is also used internally by the applicant organisation.
- Blocking competitors. The patent is not used (neither internally, nor for licensing). Rather, it is held unused within the applicant organisation in order to block competitors.
- Sleeping patents. The patent is "sleeping" in the sense that it is not employed in any of the uses described above.

Table 3.10 shows the use of patents. At the overall EU6 level, half of the patents are used internally (50.49%). About 35% are not used: specifically, 18.69% are applied for strategic reasons, and 17.44% are "sleeping" patents. Fifteen percent of the patents are exchanged in the market for technologies: 6.38% are licensed, 3.97% are both licensed and internally used, and 3.03% are used in cross-licensing agreements.

Table 3.10 also highlights the differences in the use of patents across the countries involved in the survey. France has the largest share of internally used (64.60%) and cross-licensed patents (7.35%), while the shares of "blocking" (11.61%) and "sleeping" patents (8.90%) are much smaller than the EU6 shares. Also the share of licensed and licensed & used patents in France is lower than the EU6 average. In Germany the share of sleeping patents is the largest amongst the EU6 countries (25.25%). In Spain, patents are licensed and licensed & used more than in the overall EU6 countries. In Italy inventors patent mainly for internal use (55.52%) or for blocking competitors (23.53%), while the share of sleeping patents is the smallest amongst the EU6 (9.57%). Also the exploitation of patents in the market for technologies is less diffused in Italy than in the other countries. By contrast, the Netherlands shows large shares of licensed patents (7.57%), licensed & used patents (4.67%) and cross-licensed patents (3.83%), together with a large share of blocking patents (23.46%). The Netherlands patent less than the other countries for internal use. The UK shows a distribution similar to the Netherlands. Only the share of cross-licensed patents (4.62%) is larger than in the Netherlands, and the share of licensed patents (10.21%) is the largest among the six EU countries.

Table 3.11 shows the distribution of the six patent uses by "macro" technological classes. More than half of Process Engineering and Mechanical Engineering patents are used for internal purposes (54.62% and 56.50% respectively). Only 37.93% of Chemical and Pharmaceutical patents are used internally, while about 50% of the patents in this class are held unused: 28.24% are used for blocking competitors, and 22.29% are "sleeping" patents. In line with the existing evidence on licensing activities (Anand and Khanna, 2000) Chemical and Pharmaceutical patents are licensed frequently (6.44%). Licensing & use and cross-licensing are instead used less than the average: 2.48% and 2.62% respectively. The share of cross-licensing is above the average in Electrical

Engineering and Instruments (6.09% and 4.95%), therefore confirming the findings by earlier contributions for the US firms in electronics and semiconductors (Grindley and Teece, 1997; Anand and Khanna, 2000; Hall and Ziedonis, 2001). The literature, however, seems to have underestimated the importance of patenting in Process Engineering and Mechanical Engineering: Table 3.11 shows that the share of unused patents in these technologies is the lowest among the 5 technological classes.

Table 3.10 The distribution of patent uses by country

	Internal use	Licensing	Cross-licensing	Licensing & Use	Blocking Competitors	Sleeping Patents	Total
DE	49.59%	4.74%	2.08%	3.94%	14.40%	25.25%	100.00%
ES	52.44%	8.54%	2.03%	5.28%	19.11%	12.60%	100.00%
FR	64.60%	5.42%	7.35%	2.13%	11.61%	8.90%	100.00%
IT	55.52%	5.09%	1.29%	5.00%	23.53%	9.57%	100.00%
NL	47.10%	7.57%	3.83%	4.67%	23.46%	13.36%	100.00%
UK	45.66%	10.21%	4.62%	3.10%	23.45%	12.97%	100.00%
Total	50.49%	6.38%	3.03%	3.97%	18.69%	17.44%	100.00%

Number of observations = 7,714

Table 3.11 The distribution of patent uses by macro technological class

	Internal use	Licensing	Cross-licensing	Licensing & Use	Blocking Competitors	Sleeping Patents	Total
Electrical Engineering	49.21%	3.92%	6.09%	3.59%	18.35%	18.85%	100.00%
Instruments	47.52%	9.08%	4.95%	4.25%	14.39%	19.81%	100.00%
Chemical & Pharmaceutical tech.	37.93%	6.44%	2.62%	2.48%	28.24%	22.29%	100.00%
Process Engineering	54.62%	7.36%	2.04%	4.85%	15.38%	15.74%	100.00%
Mechanical Engineering	56.50%	5.80%	1.79%	4.23%	17.39%	14.30%	100.00%
Total	50.50%	6.38%	3.02%	3.97%	18.69%	17.44%	100.00%

Number of observations = 7,711

Table 3.12 describes the distribution of the patent uses by "micro" technological classes. Consistently with Table 3.11, the largest shares of licensed patents are in Biotechnology (18.52%), followed by Agriculture and Food Chemistry (14.29%), and Chemical Engineering (12.55%). Between 9% to 11% of the total number of patents in our sample are licensed also in Medical Technologies, Pharmaceuticals & Cosmetics, Surface Technologies & Coatings, Material Processing, Textiles, & Papers, Thermal processes & Apparatus, and Environmental Technology. Moreover, in Medical Technologies, Materials & Metallurgy, and Civil Engineering more than 5% of patents are both licensed & used. Cross-licensing is frequent in Electrical Engineering technologies (like Audio-visual Technologies, Information Technologies and Semiconductors), in Instruments (like Optics, Medical Technologies and Nuclear Engineering,) in Pharmaceuticals & Cosmetics, and in Biotechnology.

As far as the internal use of patents is concerned, there are technologies in which the share of internally used patents is above the overall average (50.50%): Agricultural & Food Processing, Machinery and Apparatus, (70.91%), Handling and Printing (64.32%), Machine Tools (62.14%) and Consumer Goods and Equipment (62.79%). The patent applicants in these sectors are also more likely to invest in complementary assets for producing and distributing the final products compared to other sectors where licensing is more diffused and the "strategic" reasons for patenting are also important. In Chemicals and Pharmaceuticals there are large shares of unused patents, with the largest share of blocking patents in Organic Fine Chemistry (37.22%) and in the Chemical and Petrol industry (27.00%). Large share of sleeping patents are applied in Environmental Technologies (31.58%), Organic Fine Chemistry (30.27%) and in Information Technologies, Telecommunications, Semiconductors and Optics (from 25% to 28%).

Table 3.13 shows the use of patents by type of organisation in which the inventors were employed at the time of the innovation. Large firms use internally half of their patents, while they exchange less than 10% of them, and they do not use about 40% of their patent portfolio. More than half of the unused inventions are patented to block competitors. The large share of unused patents by large firms might also be due to the fact that large companies have the financial strength to apply for patent protection not only for important innovations, but also for less valuable ones. Therefore, as the number of patent applications increases, their average quality might decrease leading to larger shares of used patents (i.e. sleeping patents) compared to smaller companies. Indeed, due to financial constraints, the latter are more likely to apply for patents with a high expected value. Medium-sized firms use 65.62% of their patents for internal production processes and products. Small firms use 55.78% of their patents. Only 18% of patents are not used (for blocking and "sleeping" reasons), and about 26% are licensed (specifically, 14.96% are only licensed, 6.90% are licensed & used, and 3.89% are cross-licensed). As expected, public or private research organizations and university license a large fraction of their technologies and do not use them internally.

Table 3.12 The distribution of patent uses by micro technological class

ISI Technological Classes	Internal use	Licensing	Cross-licensing	Licensing & Use	Blocking Competitors	Sleeping Patents	Total
Electrical Devices, Electrical Eng. & Electrical Energy	55.52%	2.76%	3.97%	5.17%	17.93%	14.66%	100.00%
Audio-visual Technology	50.00%	7.53%	10.27%	2.74%	15.07%	14.38%	100.00%
Telecommunications	37.83%	3.48%	9.13%	2.61%	21.74%	25.22%	100.00%
Information Technology	43.71%	6.59%	5.39%	1.80%	17.96%	24.55%	100.00%
Semiconductors	46.05%	1.32%	6.58%	0.00%	18.42%	27.63%	100.00%
Optics	38.62%	6.90%	8.97%	2.07%	17.93%	25.52%	100.00%
Analysis, Measurement, & Control Technology	50.21%	8.94%	2.98%	3.62%	13.19%	21.06%	100.00%
Medical Technology	47.74%	11.56%	7.04%	7.04%	15.08%	11.56%	100.00%
Organic Fine Chemistry	23.09%	6.05%	1.79%	1.57%	37.22%	30.27%	100.00%
Macromolecular Chemistry & Polymers	44.29%	3.81%	1.90%	3.81%	24.29%	21.90%	100.00%
Pharmaceuticals & Cosmetics	34.85%	9.85%	8.33%	1.52%	25.00%	20.45%	100.00%
Biotechnology	38.89%	18.52%	5.56%	3.70%	12.96%	20.37%	100.00%
Materials & Metallurgy	44.96%	6.59%	1.55%	6.20%	16.28%	24.42%	100.00%
Agriculture, & Food Chemistry	51.02%	14.29%	2.04%	1.02%	20.41%	11.22%	100.00%
Chemical & Petrol Industry, Basic Materials Chemistry	49.43%	4.18%	1.90%	2.66%	27.00%	14.83%	100.00%
Chemical Engineering	50.21%	12.55%	3.35%	5.44%	12.97%	15.48%	100.00%
Surface Technology & Coating	48.80%	11.20%	1.60%	4.00%	16.80%	17.60%	100.00%
Materials Processing, Textiles & Paper	49.77%	10.09%	2.11%	4.23%	19.25%	14.55%	100.00%
Thermal Processes & Apparatus	54.22%	9.64%	3.01%	3.01%	16.27%	13.86%	100.00%
Environmental Technology	37.59%	9.02%	3.01%	7.52%	11.28%	31.58%	100.00%
Machine Tools	62.14%	5.36%	0.71%	5.00%	15.71%	11.07%	100.00%
Engines, Pumps & Turbines	47.71%	4.13%	3.21%	3.67%	23.39%	17.89%	100.00%
Mechanical Elements	56.25%	3.87%	0.60%	3.57%	20.24%	15.48%	100.00%
Handling & Printing	64.32%	2.62%	1.31%	4.58%	15.38%	11.78%	100.00%
Agricultural & Food Processing, Machinery & Apparatus	70.91%	7.27%	3.03%	3.03%	9.70%	6.06%	100.00%
Transport	52.42%	3.90%	1.67%	3.90%	16.91%	21.19%	100.00%
Nuclear Engineering	47.06%	5.88%	2.94%	5.88%	11.76%	26.47%	100.00%
Space Technology Weapons	51.22%	4.88%	0.00%	4.88%	14.63%	24.39%	100.00%
Consumer Goods & Equipment	62.79%	8.01%	1.29%	3.10%	16.54%	8.27%	100.00%
Civil Eng., Building & Mining	58.84%	7.93%	3.35%	7.01%	14.63%	8.23%	100.00%
Total	50.50%	6.38%	3.02%	3.97%	18.69%	17.44%	100.00%

Number of observations = 7,711

Table 3.13 The distribution of patent uses by type of inventors' employer

	Internal use	Licensing	Cross-licensing	Licensing & Use	Blocking Competitors	Sleeping Patents	Total
Large companies	49.93%	3.03%	3.03%	3.22%	21.72%	19.06%	100.00%
Medium sized companies	65.62%	5.38%	1.20%	3.59%	13.90%	10.31%	100.00%
Small companies	55.78%	14.97%	3.89%	6.90%	9.62%	8.84%	100.00%
Private Research Institutions	16.67%	35.42%	0.00%	6.25%	18.75%	22.92%	100.00%
Public Research Institutions	21.74%	23.19%	4.35%	5.80%	10.87%	34.06%	100.00%
Universities	26.25%	22.50%	5.00%	5.00%	13.75%	27.50%	100.00%
Other Governm. Institutions	41.67%	16.67%	0.00%	8.33%	8.33%	25.00%	100.00%
Other	34.04%	17.02%	4.26%	8.51%	12.77%	23.40%	100.00%
Total	50.53%	6.17%	3.06%	3.92%	18.83%	17.50%	100.00%

Number of observations = 7,556

Patent value and Patent use

Table 3.14 shows the distribution of the value of European patents across the six patent uses. The overall EU6 share of patents with a value of 10 million Euros or more is 7.4%. It increases to 9.91% for patents that are involved in cross-licensing agreements. It is 9.41% for patents that are both licensed & used, and it is 9.21% for patents that are only licensed. As expected, the share of sleeping patents with a high monetary value (10 millions Euros or more) is only 4.88%. The share of blocking patents is 7.24%. This distribution of the data is reflected in the average monetary value of the patents in the six patent uses. The average value of a licensed and cross-licensed patent is higher than the average value of a patent in any other possible use. Also the average value of a blocking patent is above the overall EU6 average.

Also the share of opposed patents is high for patents that are licensed (9.96%), and it reaches a peak of 11.11% for patents that are both licensed & used, compared to 8.13% of the EU6. Differently, the average number of forward citations is higher than the EU6 average in the case patents are sleeping (1.15), cross-licensed and produced to block competitors. Additional work with multiple correlation analysis is needed to understand the potential value and the social costs of the unused patents, which seem to be quite important in terms of their monetary value (i.e. blocking patents) or as a source of knowledge spillovers to other inventors (i.e. sleeping patents).

Table 3.14 The distribution of patent value by patent use

Patvalue	Internal use	Licensing	Cross-licensing	Licensing & Use	Blocking Competitors	Sleeping Patents	Total
<30k	5.71%	2.70%	5.19%	1.39%	10.44%	11.70%	7.23%
30k-100k	17.03%	13.93%	11.79%	10.80%	16.68%	20.71%	16.98%
100k-300k	21.04%	15.96%	16.98%	19.86%	19.72%	22.47%	20.54%
300k-1m	22.31%	24.72%	21.23%	27.87%	21.43%	20.79%	22.24%
1m-3m	15.34%	20.67%	20.28%	17.07%	17.15%	12.54%	15.76%
3m-10m	10.84%	12.81%	14.62%	13.59%	7.33%	6.90%	9.87%
10m-30m	4.04%	4.72%	4.72%	5.23%	3.35%	2.69%	3.80%
30m-100m	2.29%	1.57%	2.83%	3.48%	1.79%	1.35%	2.06%
100m-300m	0.60%	1.57%	0.94%	0.70%	0.70%	0.42%	0.67%
>300m	0.80%	1.35%	1.42%	0.00%	1.40%	0.42%	0.87%
Total	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
Average patent value	9,472 (39,551)	5,452 (17,126)	9,635 (39,207)	6,532 (30,439)	7,845 (38,039)	3,996 (22,896)	6,580 (31,450)
Average number of forward citations	0.60 (1.41)	0.85 (1.72)	1.00 (2.57)	0.93 (1.66)	0.94 (2.17)	1.15 (2.12)	0.95 (1.88)
Share of opposed patents	9.96%	11.11%	8.15%	9.04%	6.66%	5.73%	8.13%
Number of observations	492	306	233	3894	1441	1344	7710

Note: standard deviations in parenthesis. The number of observations shown in this Table refers to the number of forward citations and opposed patents. For the average patent value the number of observation is 6,903.

The importance of different motives for patenting

While the previous Section described the actual use of patents, this Section focuses on the motives that led inventors and their organisations to ask for patent protection. In the PatVal-EU survey we asked inventors to assign a score from 1 to 5 to the importance of six different motives for patenting within those organizations in which they were employed at the time of the invention.

The six motives for patenting are the following: commercial exploitation of the innovation, licensing, cross-licensing, prevention from imitation, blocking rivals, and reputation. Table 3.15 shows the average importance of these six motives for patenting by "macro" technological class (Annex A III.2 shows the distribution by country). The most important reasons for patenting are the commercial exploitation of the innovations and the prevention from imitation. In other words, inventors and organisations patent because they seek exclusive rights to exploit economically. By patenting the "inventions around" they prevent others to imitate their valuable innovations. Another reason for patenting is to block competitors that might patent similar innovations, which suggests that patents are important for competitive reasons more than for evaluating or motivating people working in the organization. Indeed, organizations do not consider reputation as being a very important reason for patenting. Also licensing and cross-licensing are not considered among the most important motivations for patenting. This is consistent with the low share of licensed patents as compared to those that are used internally and to the share of unused patents discussed in the previous Section.

There are not significant differences across "macro" technological classes in the motives that lead the applicant to ask for patent protection. Licensing is considered more important in Electrical Engineering, Instruments, and Chemical & Pharmaceutical technologies, compared to the others. Reputation is slightly more important in Electrical Engineering (and in particular in Semiconductors, as shown in Table A.12 in Annex A III.2).

Different types of employers have different motivations to patent. Table 3.16 shows that the commercial exploitation of a patent is more important for small and medium firms (4.03 and 3.91 respectively) compared to the overall importance (3.79). Licensing is more important for private and public research organizations, including universities, with a level of importance higher than 3 against the overall average of 2. Cross-licensing is an important reason for patenting for large firms. Large and medium firms also consider prevention from imitation and blocking rivals as important motives to ask for patent protection. Finally reputation is an important reason to patent for public research organizations and universities.

Annex A III.2 presents additional evidence on the use of patents and the importance of different motives for patenting. It shows data on the use of European patents and the motives for patenting according to the nationality and the number of countries in which the applicant institutions are located. It also shows the distribution of our six motives for patenting across the micro technological classes in which the patents are classified.

Table 3.15 Importance of different motives for patenting. Distribution by macro technological class.

	Electrical Engineering	Instruments	Chemical & Pharmaceutical tech.	Process Engineering	Mechanical Engineering	Total
Commercial exploitation	3.57 (1.57)	3.70 (1.60)	3.93 (1.46)	3.83 (1.57)	3.80 (1.60)	3.78 (1.56)
Licensing	2.26 (1.55)	2.19 (1.56)	2.12 (1.53)	1.98 (1.55)	1.94 (1.52)	2.06 (1.54)
Cross-licensing	2.59 (1.65)	1.98 (1.54)	1.67 (1.34)	1.56 (1.29)	1.54 (1.29)	1.78 (1.44)
Prevention from imitation	3.66 (1.55)	3.66 (1.59)	3.66 (1.63)	3.80 (1.62)	3.87 (1.57)	3.76 (1.60)
Blocking patents	3.05 (1.63)	2.82 (1.68)	3.10 (1.68)	3.02 (1.73)	2.98 (1.74)	3.00 (1.70)
Reputation	2.46 (1.57)	2.42 (1.57)	2.23 (1.52)	2.18 (1.58)	2.17 (1.53)	2.25 (1.56)

Note: standard deviations in parenthesis

Table 3.16 Importance of different motives for patenting. Distribution by type of inventors' employer.

	Large companies	Medium sized companies	Small companies	Private Research Institutions	Public Research Institutions	Universities	Other Governm. Institutions	Others	Total
Commercial exploitation	3.76 (1.54)	3.91 (1.57)	4.03 (1.55)	3.65 (1.68)	3.05 (1.65)	3.48 (1.72)	2.54 (2.26)	3.39 (1.56)	3.78 (1.56)
Licensing	1.96 (1.41)	1.76 (1.52)	2.26 (1.84)	3.58 (1.65)	3.00 (1.72)	3.15 (1.69)	2.77 (2.01)	2.80 (1.83)	2.06 (1.54)
Cross-licensing	1.96 (1.46)	1.35 (1.22)	1.32 (1.29)	1.25 (0.86)	1.54 (1.34)	1.59 (1.44)	1.15 (1.41)	1.74 (1.42)	1.79 (1.43)
Prevention from imitation	3.85 (1.50)	3.87 (1.57)	3.66 (1.77)	3.27 (1.82)	2.86 (1.85)	2.85 (1.85)	2.38 (2.10)	3.46 (1.66)	3.76 (1.59)
Blocking patents	3.08 (1.64)	3.09 (1.75)	2.87 (1.86)	2.58 (1.75)	2.05 (1.67)	2.42 (1.75)	2.15 (2.03)	2.54 (1.73)	3.01 (1.70)
Reputation	2.26 (1.50)	2.14 (1.61)	2.14 (1.69)	2.44 (1.67)	2.91 (1.69)	2.94 (1.65)	1.23 (1.74)	1.89 (1.42)	2.27 (1.55)

Note: standard deviations in parenthesis

3.4 Creation of new businesses from the patented invention

Recent contributions highlight the role of intellectual property rights to encourage the creation of new firms, and ultimately to increase the rate of employment. Small, specialised and innovative firms can be important ingredients for enhancing the employment and the economic performances of specific regions (see Eurostat, 2002). A patent system that increases the probability of formation of such firms can therefore produce beneficial economic effects. However the empirical evidence on this issue is limited. The literature focuses on the creation of firms by university inventors, and investigates the phenomenon in the US. The evidence for Europe is inexistent.

The PatVal-EU survey provides information about the creation of new ventures by using the patented innovations. Figure 3.3 reports the share of patents in the PatVal-EU database used to start-up a new firm. At the overall EU6 level, 5.13% of patents give rise to a new firm. This share is the highest in the UK (9.69%) and in Spain (9.27%). It is the lowest in Germany (2.72 %) and in France (1.63%).

Figure 3.3 Share of new firms from patented inventions by country

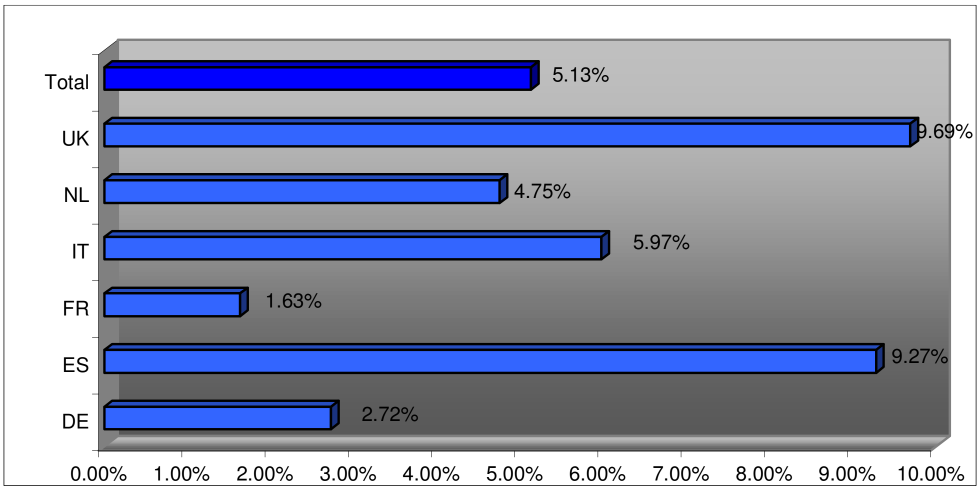


Table 3.17 shows the European regions at the NUTS2 level in which the share of new firms originated from a patent is above the EU6 average (5.13%). Consistently with the share of start-ups by country, Table 3.17 shows that the European regions with the largest share of new firms created by using the patented invention are in the UK. Sixteen out of 25 regions in Table 3.17 are British; 3 are Italians; only 2 regions are German, 2 are Spanish and 2 are Dutch. Table A.15 in Annex AIII.3 shows the regions with a share of start-ups lower than the EU average.

Figure 3.4 shows the share of patents that give rise to new ventures by macro-technological classes. In Instruments the share of new firms is the largest (7.50%), followed by Process Engineering (5.56%) and Mechanical Engineering (5.38%). In Chemicals & Pharmaceuticals only 3.08% of patents are used for creating a new firm.

Table 3.18 shows detailed information about the creation of new firms by "micro" technological classes. In Space Technology Weapons and in Medical Technology the share of patents that gave rise to a new firm is 10.53% and 10.00% respectively. Agricultural & Food Processing, Machinery & Apparatus, Audio-visual Technology, Biotechnology, Civil Engineering, Consumer Goods & Equipment follow with shares above 8% of new firm creation from the patented innovations. In many of the other technologies the share of patents that led to new firm formation is close to the overall average. The least active sectors in this sense are Semiconductors, Organic Fine Chemistry, Macromolecular Chemistry & Polymers where the share of new firms is 2% or smaller.

Figure 3.5 shows the creation of new firms by type of inventors' employers. About 17% of the patents applied by small firms are used to create a new business. This share falls to 5.06% for medium-sized firms, and it drops to 1.91% for large firms. The share of new firm formation for universities and private research organization is comparatively large, as it is 16.32% and 14.58% respectively.

Table 3.17 Share of new firms from patented inventions by European regions (NUTS2)

Country	NUTS2	% New firms	N
UK	Eastern Scotland	18.75%	32
UK	Leicestershire, Rutland and Northants	16.67%	36
UK	Inner London	16.67%	48
UK	West Yorkshire	14.52%	62
UK	Essex	13.95%	43
UK	Merseyside	13.16%	38
ES	Comunidad de Madrid	12.82%	39
UK	Hampshire and Isle of Wight	12.73%	55
UK	Berkshire, Bucks and Oxfordshire	10.66%	122
UK	Gloucestershire, Wiltshire and North Somerset	10.34%	87
IT	Veneto	10.00%	110
UK	Outer London	9.78%	92
UK	Bedfordshire, Hertfordshire	9.76%	41
UK	East Anglia	9.52%	105
NL	Noord-Holland	9.40%	117
DE	Gießen	9.09%	33
UK	Derbyshire and Nottinghamshire	8.70%	46
ES	Cataluña	7.69%	104
IT	Emilia-Romagna	6.75%	163
UK	Tees Valley and Durham	6.45%	31
NL	Gelderland	6.25%	128
UK	West Midlands	5.88%	85
IT	Lombardia	5.46%	403
DE	Karlsruhe	5.26%	133
UK	Greater Manchester	5.13%	78
Total		5.13%	7394

Note: This Table includes the European regions in which the share of new firms from patented inventions is above the EU6 average and the number of observation in each region is ≥30.

Figure 3.4 Share of new firms from patented inventions by macro technological class

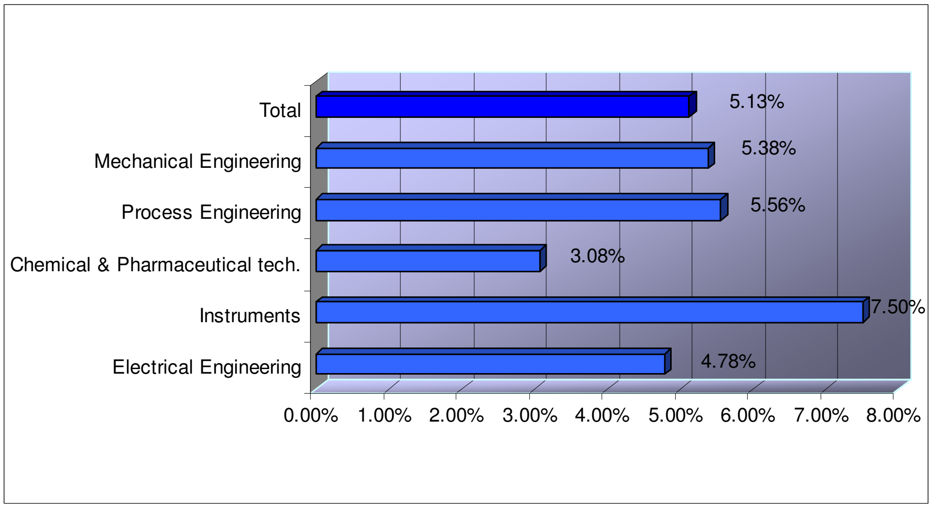
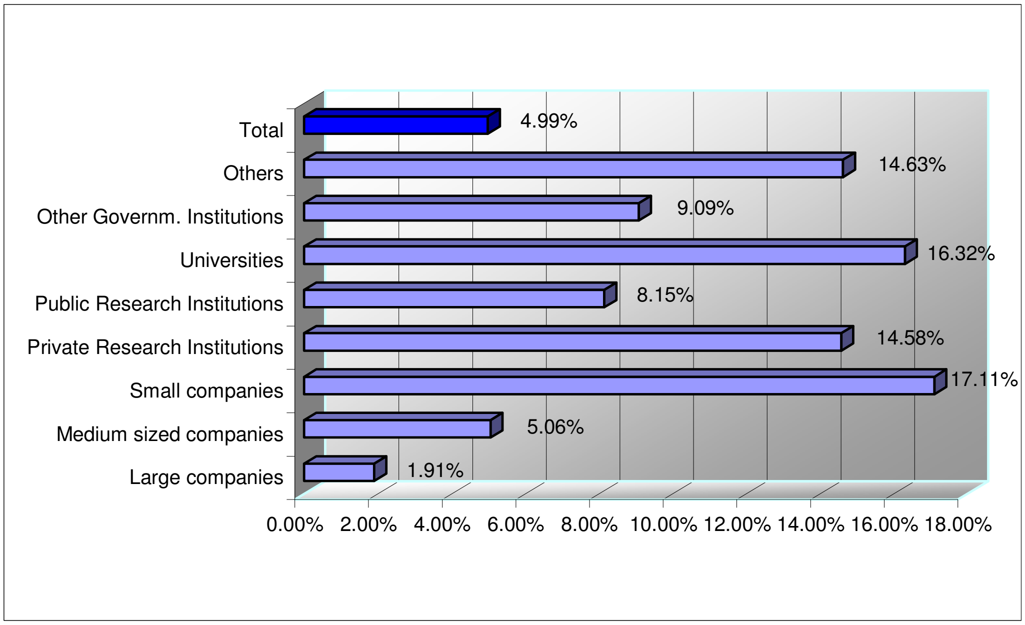


Table 3.18 Share of new firms from patented inventions by macro technological class

Technological Class	%
Space technology weapons	10.53%
Medical technology	10.00%
Agricultural & Food Processing, Machinery & Apparatus	9.20%
Audio-visual technology	8.67%
Biotechnology	8.62%
Civil Eng., Building & Mining	8.52%
Consumer Goods & Equipment	8.06%
Chemical engineering	7.46%
Analysis, Measurement, & Control Technology	7.37%
Nuclear engineering	6.45%
Materials Processing, Textiles & Paper	6.27%
Information technology	6.13%
Agriculture, & Food Chemistry	5.38%
Materials & Metallurgy	5.19%
Total	**5.13%**
Thermal Processes & Apparatus	4.91%
Optics	4.86%
Environmental technology	4.84%
Pharmaceuticals & Cosmetics	4.72%
Transport	4.72%
Telecommunications	4.27%
Handling & Printing	4.17%
Chemical & Petrol Industry, Basic Materials Chemistry	4.10%
Electrical Devices, Electrical Eng. & Electrical Energy	3.97%
Mechanical Elements	3.69%
Machine tools	3.02%
Engines, Pumps & Turbines	2.86%
Surface Technology & Coating	2.63%
Macromolecular Chemistry & Polymers	2.00%
Organic fine chemistry	1.77%
Semiconductors	1.43%

Figure 3.5 Share of new firms from patented inventions by type of inventors' employer



Annex A III.3 shows additional Figures on the creation of new businesses from the patented inventions. They distinguish between individual inventors who applied for the patent, and applicant organisations. They also show the share of patents used to create a new firm as a function of the number of countries in which the applicants are located.

3.5 Collaboration, Spillovers and the Sources of Knowledge in the Invention Process

This Section describes the sources of knowledge used in the innovation process leading to the PatVal-EU patents. Patent citations have typically been used in the literature to analyse the extent to which knowledge is transferred among individuals, organisations and geographical locations (i.e. Jaffe, 1993; Verspagen, 1997). The PatVal-EU data provides original and direct information about the sources of such spillovers, whether they are generated within the firm, or if they are accessed from external sources, being these individual inventors, other companies, universities, public or private research organizations, scientific meetings or earlier patents.

Collaboration amongst inventors in the innovation process

Table 3.19 shows the extent to which individual inventors collaborate in the research activity leading to a patent. At the overall EU6 level, only one third of the PatVal-EU patents (37.36%) is developed by "individual" inventors. This share varies across countries. The share of individual inventors' patents is the largest in Spain (57.14%). The UK and Italy follow with 40.68% and 40.15% of patents developed by individual inventors. The Netherlands (33.27%), France (36.34%) and Germany (35.24%) are below the EU6 average.

Table 3.19 also indicates whether the multiple inventors (i.e. co-inventors) involved in the development of the patents are affiliated to the primary inventor's organization, or to other organizations. This is a useful piece of information to understand the extent of collaboration among institutions that occurs by means of the collaboration among individual researchers. By distinguishing between internal and external co-inventors, Table 3.19 reveals the occurrence of knowledge spillovers between inventors located in different organizations. This information is difficult to obtain from existing – and "official" – data like the patent document.

The EU6 share of patents developed by multiple inventors affiliated to different organizations is 23.94%. In the UK this share reaches 35.52%. It falls to 16.05%, 19.29% and 21.88% in Italy, France and Spain respectively. In these countries, therefore, the networks of inventors tend to be within the same organization, with a limited role of external linkages. The Netherlands and Germany are close to the EU6 average.

Table 3.19 Affiliation of the inventors involved in the development of the patents. Distribution by country.

	Patents developed with internal co-inventors	Patents developed with external co-inventors	Total	Share of Individual inventors' patents
DE	76.18%	23.82%	100%	35.24%
ES	78.13%	21.88%	100%	57.14%
FR	80.71%	19.29%	100%	36.34%
IT	83.95%	16.05%	100%	40.15%
NL	76.14%	23.86%	100%	33.27%
UK	64.48%	35.52%	100%	40.68%
Total	76.06%	23.94%	100%	37.36%

Table 3.20 shows the share of co-applied patents, and distinguishes between patents applied together by organizations belonging to the same group, and patents co-applied by independent companies. Related to this, Table 3.20 investigates whether the collaboration among inventors described in Table 3.19 shows up also in the collaboration among the organizations that apply together for a patent. The EU6 share of patents applied by single applicants is 93.86% with little variation across countries. The share of co-applied patents reaches a peak of 96.63% in Spain, while it is the lowest in France (67.05%). By comparing these data with those in Table 3.19 it appears that the extent to which inventors affiliated to different organizations collaborate does not show up in the number of patent applications filled out by multiple applicants. This also confirms that the collaboration among inventors belonging to different institutions is not visible in the standard information provided by the patent document. Annex A III.4 (Tables A.16 to A.23) shows additional data on the patents applied by single applicants versus those applied by multiple applicants either independent or from the same corporate group.

Table 3.20 Number of applicant institutions in a patent. Distribution by country.

	Patents applied with single applicant	Patents applied with multiple organisations from the same group	Patents applied by multiple independent organisations	Total
DE	95.01%	1.88%	3.11%	100.00%
ES	96.63%	0.37%	3.00%	100.00%
FR	67.05%	1.16%	3.88%	100.00%
IT	79.95%	0.67%	3.36%	100.00%
NL	91.81%	4.89%	3.29%	100.00%
UK	92.15%	4.99%	2.85%	100.00%
Total	93.86%	2.55%	3.58%	100.00%

The rest of this section focuses on patents produced by multiple inventors, and distinguishes between inventors all "internal" to the same organisation (i.e. inventors affiliated to the same institution) and "external" inventors (i.e. inventors affiliated to different institutions). By using these data from the PatVal-EU survey we have the possibility to investigate the extent of collaboration between different organisations in the innovation process. Table 3.21 shows the share of patents invented by multiple inventors in the five "macro" technological classes. The share of patents developed by individual inventors is low in Chemicals & Pharmaceuticals (14.21%) compared to the overall EU6 average (37.36%). It is the largest in Mechanical Engineering where individual inventors develop 49.29% of the patents. The share of individual inventors' patents in Electrical Engineering, Instruments and Process Engineering is slightly above the European average. Differently, when patents are developed by teams of multiple inventors, most of these collaborations are among researchers employed in the same organisation. If one conditions upon the multiple inventors' patents, about 75% of the collaborations are among inventors affiliated to the same organisation. In Instruments (28.79%) and Process Engineering (25.68%) the share of patents developed in collaboration with external co-inventors is higher then the EU6 average. The sector in which the networks of inventors tend to be more frequently among people from the same organisation is Electrical Engineering where 19.64% of co-invented patents are invented by "external co-inventors".

Table 3.21 Affiliation of the inventors involved in the development of the patents. Distribution by "macro" technological class.

	Patents developed with internal co-inventors	Patents developed with external co-inventors	Total	Share of Individual inventors' patents
Electrical Engineering	80.36%	19.64%	100%	38.99%
Instruments	71.21%	28.79%	100%	38.69%
Chemical & Pharmaceutical tech	77.19%	22.81%	100%	14.21%
Process Engineering	74.32%	25.68%	100%	38.79%
Mechanical Engineering	75.95%	24.05%	100%	49.29%
Total	76.05%	23.95%	100%	37.36%

Let's now turn to the institution-specific effect on the probability of establishing collaborations among inventors affiliated to different organisations. Table 3.22 shows the share of individual inventors' patents, internal co-inventors' patents, and external co-inventors' patents for different types of inventors' employers. As expected, within the group of private companies, inventors in large firms develop the smallest share of individual inventors' patents and the largest share of internal co-inventors' patents. This might be due to the presence of large research laboratories in the big corporations where a large number of complementary capabilities are employed. These big research facilities within the large companies lead to the internalisation of knowledge spillovers by means of firm specific coordination and organisation capabilities. Differently, small companies have the largest share of individual inventors' patents (61.64%). Small companies also develop the largest share of patents invented by external co-inventors (39.74%) compared to 18.60% of the large companies and 23.91% of the medium-sized enterprises. Universities and public research institutions have the lowest share of individual inventors' patents (18.25% and 16.85%). Moreover, the multiple inventors' patents that they produce are frequently invented by inventors affiliated to external organisations: 58.48% and 45.27% of all multiple inventors' patents developed by universities and public research institutions involve collaborations between inventors from different organisations.

Table 3.22 Affiliation of the inventors involved in the development of the patents. Distribution by type of primary inventors' employer

	Patents developed with internal co-inventors	Patents developed with external co-inventors	Total	Share of Individual inventors' patents
Large companies	81.40%	18.60%	100.00%	31.68%
Medium sized companies	76.09%	23.91%	100.00%	48.41%
Small companies	60.26%	39.74%	100.00%	61.64%
Private Research Institutions	65.79%	34.21%	100.00%	38.71%
Public Research Institutions	54.73%	45.27%	100.00%	16.85%
Universities	41.52%	58.48%	100.00%	18.25%
Other Governm. Institutions	57.14%	42.86%	100.00%	50.00%
Others	40.00%	60.00%	100.00%	64.29%
Total	76.56%	23.44%	100.00%	36.85%

We focus now on the "external co-inventors". Table 3.23 shows their affiliation, and their distribution across the 6 countries involved in the PatVal-EU survey. For the overall EU6, large companies are the research partners in about half of the collaborations. Small companies and universities come second (20.36%) and third (15.58%). In Germany, the share of collaborations with inventors employed in large companies (64.38%) is larger than the EU6 share, followed by Italy (51.72%). Medium sized enterprises are particularly important in Spain (23.81%) compared to the EU6 share. Inventors employed in small companies are the partners of 25.80% of the patents developed through external collaborations in Germany, and 23.00% of those in the UK. As far as Universities are concerned, they are important partners in Italy (26.72%) and in Spain (23.81%) compared to the overall EU6.

Table 3.23 External co-inventors. Distribution by country and by affiliation of the "external" inventors

	Affiliation of the "external" co-inventors						
	Large companies	Medium sized companies	Small companies	Private Research Institutions	Public Research Institutions	Universities	Number obs.
DE	64.38%	9.82%	25.80%	3.20%	10.96%	5.71%	438
ES	33.33%	23.81%	19.05%	4.76%	23.81%	9.52%	21
FR	49.71%	4.05%	16.18%	15.03%	17.34%	4.62%	173
IT	51.72%	7.76%	14.66%	6.90%	26.72%	11.21%	116
NL	26.40%	6.18%	10.67%	3.93%	12.92%	16.85%	178
UK	42.51%	8.01%	23.00%	4.88%	18.12%	9.41%	287
Total	49.79%	8.08%	20.36%	5.77%	15.58%	8.66%	1,213

Note: The sum of shares by row can be larger than 100% because each patent's inventor might have 1 or more co-inventors employed in different organisations.

Table 3.24 shows that there is little variation across "macro" technological classes in the extent to which inventors employed in large companies are involved in the collaborations with the organisations of the PatVal-EU inventors. The presence of small companies is particularly large in Instruments (31.25%) compared to the EU6 share (20.35%), while they have a very limited role in the collaborative networks among inventors in Chemicals and Pharmaceuticals (11.32%). By contrast, in Chemicals and Pharmaceuticals, inventors working in the Academia enter a large fraction of inter-inventors collaborations (25.16%) compared to overall EU6 share.

Table 3.24 External co-inventors. Distribution by "macro" technological class and by affiliation of the "external" inventors

	Affiliation of the "external" co-inventors						
	Large companies	Medium sized companies	Small companies	Private Research Institutions	Public Research Institutions	Universities	Number obs.
Electrical Engineering	49.68%	7.74%	20.00%	7.74%	19.35%	7.74%	155
Instruments	34.18%	6.96%	31.65%	5.06%	17.72%	13.29%	158
Chemical & Pharmaceutical tech.	50.83%	5.28%	11.55%	8.91%	25.08%	4.29%	303
Process Engineering	53.50%	9.87%	21.02%	4.46%	12.10%	7.96%	314
Mechanical Engineering	53.36%	9.89%	22.97%	3.18%	6.01%	12.01%	283
Total	49.79%	8.08%	20.36%	5.77%	15.58%	8.66%	1,213

Note: The sum of shares by row can be larger than 100% because each patent's inventor might have 1 or more co-inventors employed in different organisations.

Table 3.25 looks at the type of institutional networks that are developed through the collaborations among "external" inventors. In most of the cases, large companies collaborate with other large companies (65.90%). Large companies also develop research collaborations with small companies (14.02%) and with the Universities (14.31%). Also small firms tend to develop linkages with other small firms (41.86%), and with large companies (27.33%). Similarly, Universities tend to establish formal collaborations with other Universities (31.50%) and with large companies (37.80%).

Table 3.25 External co-inventors. Distribution by type of employer of the interviewed inventors and by affiliation of the "external" inventors

Employer Type	Affiliation of the "external" co-inventors						
	Large companies	Medium sized companies	Small companies	Private Res. Institutions	Universities	Others	Number obs.
Large companies	65.90%	3.90%	14.02%	4.05%	14.31%	7.80%	692
Medium sized companies	20.22%	39.33%	19.10%	5.62%	12.36%	7.87%	89
Small companies	27.33%	11.63%	41.86%	5.23%	9.88%	12.21%	172
Private Research Institutions	25.00%	16.67%	16.67%	0.00%	33.33%	25.00%	12
Public Research Institutions	27.69%	4.62%	33.85%	23.08%	18.46%	3.08%	65
Universities	37.80%	7.87%	19.69%	9.45%	31.50%	7.09%	127
Other Governm. Institutions	33.33%	0.00%	0.00%	0.00%	0.00%	66.67%	3
Others	27.27%	0.00%	54.55%	0.00%	0.00%	36.36%	11
Total	50.73%	8.28%	20.58%	5.89%	15.63%	8.71%	1,171

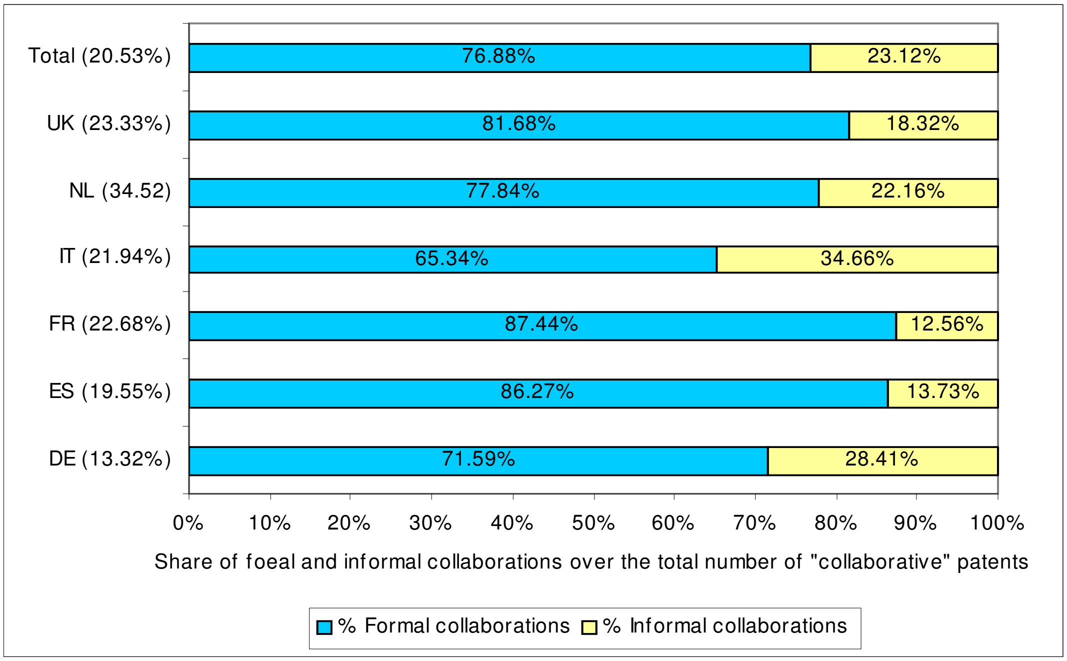
Note: The sum of shares by row can be larger than 100% because each patent's inventor might have 1 or more co-inventors employed in different organisations.

Formal and informal collaborations in research

The PatVal-EU inventors were asked to report if they established any formal or informal collaboration with other partners to develop the innovation. This information provides additional data on the extent of collaboration among different organisations while developing the innovation. The share of "collaborative" patents (i.e. patents developed in collaboration with other partners) is shown in Figure 3.6 in parentheses close to the country names. The EU6 share of patents produced by using external collaborations is 20.53%. It is higher in the Netherlands (34.52%). The UK, France, Italy and Spain are close to the EU6 average. Only 13.32% of German patents are invented in research projects that involve collaboration with external institutions.

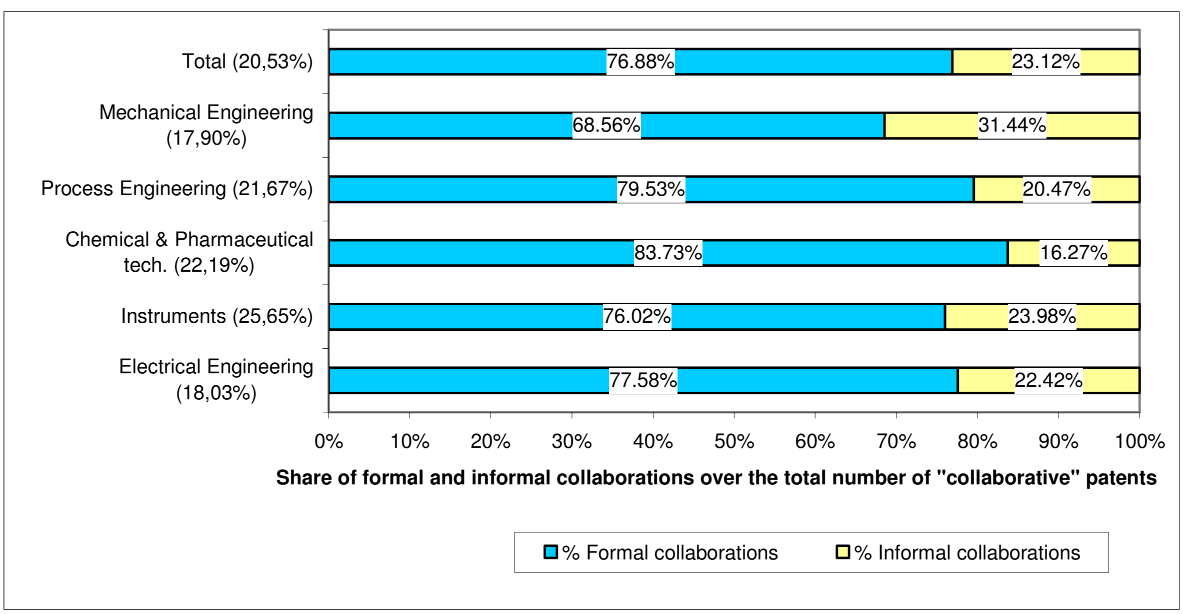
Figure 3.6 also shows the share of formal and informal collaborations over the total number of "collaborative" patents. By formal collaborations we mean well-defined contracts among the parties to collaborate over an R&D project. They cover 76.88% of the collaborations set up by firms and institutions for a common research project leading to a patent. About one fourth of the collaborations, however, are informal, suggesting that there are knowledge spillovers among inventors and institutions that are not mediated by any apparent market mechanism. In Italy (65.34%) and in Germany (71.59%) the share of formal collaborations is lower than the EU6 share. It is particularly large in France (87.44%) and in Spain (86.27%).

Figure 3.6 Formal vs. Informal collaborations amongst institutions. Distribution by country



In terms of "macro" technological classes, collaborations amongst organisations are frequent in Instruments (25.65%), Chemicals & Pharmaceuticals (22.19%) and Process Engineering (21.67%) compared to the EU6 share (20.53%). They are less frequent in Mechanical Engineering (17.90%) and Electrical Engineering (18.03%). In terms of formal vs. informal collaborations, the share of informal collaborations is larger than the EU6 average in Mechanical Engineering (31.44%). At the opposite extreme, collaborations in Chemicals & Pharmaceuticals tend to be formalised: only 16.27% of the total number of collaborations among organizations is done on informal bases. In the other three technological classes the share of informal collaborations is close to the EU6 average.

Figure 3.7 Formal vs. Informal collaborations amongst institutions. Distribution by "macro" technological class



Annex A III.4 provides additional data on the extent of collaboration among different institutions to develop a patent. The Tables in this Annex look at the distribution of formal vs. informal collaborations by micro technological classes, by type of inventors' employer, by nationality and number of countries in which the applicants are located. Tables A.28 to A.30 in Annex A III.4 focus on formal collaborations. They show the share of patents invented in collaboration with different external partners (i.e. large companies, medium sized companies, small companies, private research institutions, Universities, and "others" as a residual category) according to the nationality and the number of countries in which the patents' applicants are located, and to the 30 micro technological class in which the PatVal-EU patents are classified.

The role of geographical proximity for collaboration

To explore further the importance of knowledge spillovers among researchers in the innovation process, this Section highlights the role of geographical proximity in fostering knowledge exchange among the inventors. We use a scale from 1 to 5 for the importance of 4 different types of interaction: (1) interaction with people internal to the inventor's organization, and geographically close (i.e. less than one hour to reach physically the partner); (2) interaction with people internal to the inventor's organization, and geographically distant (i.e. more than one hour to reach physically the partner); (3) interaction with people external to the inventor's organization, and geographically close; (4) interaction with people external to the inventor's organization, and geographically distant.

Table 3.26 indicates that the interaction with other members of the same organization are on average more important than the interaction with people affiliated to other organizations, especially if people from the same organization are geographically close. For the overall EU6, the importance of the interaction with people belonging to the same organization of the inventor (including affiliates), that typically takes less than one hour to be reached, ranks first (3.02). This is so for all the six countries. When it takes more than one hour to reach the location of the other researcher, the inventors rank very similarly the importance of the interaction with people from the same organisation and from other organisations (1.31 and 1.32 respectively). Again, all the six countries are lined up in the same ranking. Only in Spain the affiliation to the same firm seems to be very important to develop linkages among the inventors, being them geographically close or distant. A common pattern to all countries is that the interaction with researchers affiliated to different organizations that are geographically close is the least important form of collaboration. This suggests that in general geographical proximity is not crucial for developing research linkages among individuals that are affiliated to different institutions.

Table 3.27 reports the role of the different types of interactions by European regions at the NUTS2 level. Table 3.27 lists the regions in which the importance of interaction with people affiliated to external organizations that are geographically close is larger than the EU6 average. The regions in which this type of interaction is evaluated as being most important are listed in the top part of the Table. In a large fraction of these very same regions other forms of interaction are also more important than those highlighted by the EU6 average. This suggests that the geographical proximity among the inventors might not be the key explanation for the importance of external interactions. A deeper understanding of the determinants of spillovers in the innovations process due to geographical proximity is needed through non parametric and multiple regression analysis. This will be performed in Lot 2 of this project.

Table 3.26 Importance of the interaction with other people while developing the innovation. Distribution by country.

	DE	ES	FR	IT	NL	UK	Total
Close & Internal	2.88 (1.91)	3.51 (1.83)	3.20 (1.80)	2.53 (1.92)	3.31 (1.85)	3.24 (1.81)	3.02 (1.88)
Distant & Internal	1.07 (1.55)	2.85 (2.18)	1.42 (1.69)	1.12 (1.65)	1.23 (1.65)	1.69 (1.84)	1.31 (1.70)
Close & External	0.73 (1.33)	0.73 (1.50)	1.41 (1.71)	0.57 (1.19)	0.85 (1.45)	0.96 (1.44)	0.88 (1.45)
Distant & External	1.25 (1.75)	0.94 (1.63)	1.53 (1.80)	1.08 (1.67)	1.30 (1.76)	1.54 (1.83)	1.32 (1.77)

Note: standard deviations in parenthesis

Table 3.27 Importance of the interaction with other people while developing the innovation. Distribution by European regions (NUTS2).

Country	NUTS2	Close & Internal	Distant & Internal	Close & External	Distant & External	N
FR	Haute-Normandie	3.28 (1.91)	1.28 (1.78)	2.03 (1.96)	1.64 (2.14)	36
FR	Provence-Alpes-Côte d'azur	3.20 (1.82)	1.58 (1.84)	1.85 (1.94)	1.80 (1.99)	55
FR	Centre	3.39 (1.71)	1.61 (1.73)	1.70 (1.86)	1.97 (1.87)	61
FR	Aquitaine	2.97 (1.87)	1.89 (1.94)	1.51 (1.87)	1.74 (1.77)	35
FR	Rhône-Alpes	3.28 (1.74)	1.43 (1.66)	1.45 (1.70)	1.50 (1.74)	269
UK	Merseyside	3.19 (1.61)	1.89 (1.84)	1.44 (1.76)	2.09 (1.95)	37
UK	Inner London	3.29 (1.83)	1.73 (1.83)	1.43 (1.84)	2.15 (2.01)	48
FR	Bourgogne	2.70 (1.99)	1.13 (1.56)	1.43 (1.82)	1.76 (1.90)	46
FR	Pays de la Loire	3.13 (1.74)	1.74 (1.94)	1.43 (1.70)	1.53 (1.90)	47
FR	Nord - pas-de-Calais	2.88 (1.78)	1.46 (1.77)	1.40 (1.73)	1.42 (1.81)	48
FR	Île de France	3.34 (1.80)	1.42 (1.69)	1.33 (1.69)	1.46 (1.76)	420
FR	Midi-Pyrénées	2.91 (1.76)	1.48 (1.63)	1.28 (1.44)	1.36 (1.71)	67
ES	Comunidad de Madrid	3.44(1.84)	3.09 (2.11)	1.26 (1.94)	1.53 (1.97)	36
FR	Picardie	3.28 (1.67)	0.92 (1.64)	1.21 (1.73)	0.92 (1.48)	39
UK	Derbyshire and Nottinghamshire	3.05 (1.95)	1.68 (1.92)	1.20 (1.64)	1.34 (1.80)	43
UK	Leicestershire, Rutland and Northants	3.69 (1.49)	1.44 (1.45)	1.16 (1.31)	1.97 (1.66)	35
UK	Bedfordshire, Hertfordshire	3.15 (1.88)	1.08 (1.44)	1.15 (1.68)	1.64 (1.95)	41
FR	Languedoc-Roussillon	3.23 (1.79)	0.83 (1.13)	1.13 (1.65)	1.93 (2.16)	40
NL	Zuid-Holland	3.26 (1.83)	1.32 (1.74)	1.10 (1.65)	1.41 (1.82)	183
DE	Unterfranken	2.98 (1.77)	0.95 (1.41)	1.09 (1.55)	1.51 (1.84)	55
UK	West Midlands	2.83 (1.75)	1.46 (1.72)	1.07 (1.59)	1.64 (1.85)	80
NL	Utrecht	3.22 (1.79)	1.09 (1.63)	1.05 (1.61)	1.14 (1.69)	65
UK	Outer London	3.37 (1.64)	1.46 (1.73)	1.00 (1.52)	1.24 (1.75)	41
UK	Gloucestershire, Wiltshire and north Somerset	3.33 (1.82)	1.86 (1.88)	1.00 (1.43)	1.22 (1.61)	86
UK	East Anglia	3.50 (1.63)	1.32 (1.55)	0.98 (1.40)	1.52 (1.72)	105
FR	Alsace	3.02 (1.88)	1.18 (1.53)	0.98 (1.36)	1.40 (1.76)	60
UK	Berkshire, Bucks and Oxfordshire	3.09 (1.71)	1.55 (1.69)	0.95 (1.46)	1.31 (1.70)	120
DE	Düsseldorf	2.75 (1.96)	1.18 (1.65)	0.92 (1.54)	1.17 (1.69)	298
Total		3.02 (1.88)	1.31 (1.70)	0.88 (1.45)	1.32 (1.77)	8588

Note: This Table lists the European regions for which the importance of Close & External interactions is above the EU6 average.

By using the same scale from 1 to 5, Table 3.28 shows the importance of the four forms of interaction in the five "macro" technological classes in which the patents are classified. The results are very similar to those in Table 3.26: the interaction with people belonging to the same organization of the inventor that takes less than one hour to be reached ranks first in all the technological classes. When the researchers are geographically distant, the importance of the affiliation to the same organization is ranked very similarly to the affiliation of the inventors to other organizations. This is so for all the five technologies. Finally, Table 3.28 confirms that geographical proximity is not a key factor for the collaboration to take place. The interaction with researchers affiliated to different organizations that are geographically close is the least important form of collaboration.

Table 3.28 Importance of the interaction with other people while developing the innovation. Distribution by "macro" technological class

	Electrical Engineering	Instruments	Chemicals & Pharmaceuticals	Process Engineering	Mechanical Engineering	Total
Close&Internal	3.20 (1.80)	2.93 (1.89)	3.40 (1.76)	2.93 (1.92)	2.79 (1.93)	3.02 (1.88)
Distant&Internal	1.33 (1.67)	1.30 (1.68)	1.46 (1.76)	1.28 (1.72)	1.23 (1.66)	1.31 (1.70)
Close&External	0.81 (1.38)	0.93 (1.50)	0.83 (1.41)	0.93 (1.49)	0.90 (1.47)	0.88 (1.45)
Distant&External	1.26 (1.72)	1.51 (1.84)	1.23 (1.72)	1.39 (1.82)	1.28 (1.75)	1.32 (1.77)

Note: standard deviations in Italic

Finally, Table 3.29 shows the importance of the different forms of interaction by type of inventors' employer. The importance of the interaction among people who are geographically close and affiliated to the same organization ranks first for the inventors employed in private companies, being they large, medium and small firms. The affiliation to the same organization together with the geographical proximity among the researchers are the most important type of interaction also for the inventors employed in public research institutions, Universities and other government institutions. Once the researchers are geographically distant, the affiliation to the same organization and to different institutions is ranked similarly. Like in Tables 3.26 and 3.28, the interaction with people affiliated to different organizations located in the same geographical area ranks last. Only for the inventors employed by Universities and private research laboratories, this type of interaction with people affiliated to other organizations that are geographically close ranks second.

Annex A III.4 provides additional Tables on the importance of geographical proximity for fostering collaborations among inventors in the 30 micro technological classes in which the PatVal-EU patents are classified, and according to the nationality and to the number of countries in which the patents' applicants are located. It also shows the importance of geographical proximity for establishing research interactions in the European regions at the NUTS2 level when the average level of importance of "close & external" interaction is lower than the EU6 average.

Table 3.29 Importance of the interaction with other people while developing the innovation. Distribution by type of inventors' employer

	Large companies	Medium sized companies	Small companies	Private Research Institutions	Public Research Institutions	Universities	Other Governm. Institutions	Others	Total
Close&Internal	3.23 (1.79)	2.96 (1.83)	2.26 (2.03)	1.84 (1.99)	3.16 (1.89)	2.74 (2.04)	2.31 (2.29)	1.34 (1.87)	3.04 (1.88)
Distant&Internal	1.38 (1.71)	1.26 (1.72)	1.08 (1.65)	0.95 (1.55)	1.25 (1.73)	1.23 (1.70)	1.55 (2.25)	0.98 (1.53)	1.31 (1.70)
Close&External	0.85 (1.41)	0.80 (1.38)	1.02 (1.62)	0.78 (1.43)	1.00 (1.47)	1.14 (1.66)	1.45 (1.92)	0.98 (1.78)	0.88 (1.45)
Distant&External	1.25 (1.72)	1.27 (1.76)	1.46 (1.87)	1.98 (2.03)	1.77 (1.91)	2.07 (1.97)	2.00 (2.12)	1.58 (2.02)	1.32 (1.77)

Note: standard deviations in parenthesis

The Sources of Knowledge

This Section looks at the sources of knowledge used by the PatVal-EU inventors to develop the innovations. By using a scale from 1 to 5 for their importance, we consider the following sources of innovation: 1) the knowledge developed in university and non-university laboratories; 2) the scientific literature; 3) the participation in conferences and workshops; 4) earlier patents; 5) the firm's users; 6) the firm's suppliers; 7) the firm's competitors.

Table 3.30 shows the average importance of each source of innovation. At the overall EU6 level, the firm's users rank first (2.88). The patent literature and the scientific literature are in the second and third positions (2.60 and 2.55 respectively), followed by the firm's competitors (2.15), the participation in technical conferences and workshops (1.67) and the interaction with the firm's suppliers (1.55). The knowledge coming from university and non-university research laboratories is at the bottom of the ranking with an average importance of 1.35. This ranking holds with only small variations in each of the 6 EU countries in the PatVal-EU survey.

Table 3.30 Importance of different sources of knowledge. Distribution by country.

	DE	ES	FR	IT	NL	UK	Total
Laboratories	1.40 (1.69)	1.21 (1.79)	1.41 (1.73)	0.77 (1.50)	1.78 (1.88)	1.38 (1.80)	1.35 (1.74)
Scientific literature	2.71 (1.84)	2.37 (2.01)	2.35 (1.94)	2.50 (1.97)	2.4 (1.74)	2.54 (1.93)	2.55 (1.89)
Conferences	1.99 (1.78)	1.20 (1.63)	1.51 (1.65)	1.36 (1.71)	1.55 (1.56)	1.55 (1.68)	1.67 (1.72)
Patents	2.83 (1.86)	2.76 (1.83)	2.62 (1.93)	2.14 (1.94)	2.40 (1.74)	2.59 (1.95)	2.60 (1.90)
Users	3.25 (1.90)	2.50 (1.95)	2.40 (2.00)	2.64 (2.03)	2.81 (1.88)	2.8 (2.02)	2.88 (1.98)
Suppliers	1.58 (1.71)	1.26 (1.53)	1.73 (1.81)	1.04 (1.57)	1.56 (1.64)	1.7 (1.83)	1.55 (1.73)
Competitors	2.42 (1.87)	1.88 (1.72)	2.38 (1.96)	1.67 (1.84)	2.00 (1.70)	1.90 (1.84)	2.15 (1.87)

Note: standard deviations in parenthesis

Table 3.31 looks at the importance of the sources of knowledge by macro technological classes. The ranking is similar to that in Table 3.30 in four out of five classes (i.e. Electrical Engineering, Instruments, Process Engineering, and Mechanical Engineering). The firm's users rank first; the patent literature and the scientific literature are second, and the knowledge coming from the university and non-university laboratories is the last source of knowledge used by the PatVal-EU inventors. Differently, in Chemicals & Pharmaceuticals the patent literature and the scientific literature are the most important sources of knowledge (3.46 and 3.66 respectively), followed by the firm's users (2.25). The research laboratories, however, are still at the bottom of the ranking, before the knowledge provided by the firm's suppliers.

Table 3.31 Importance of different sources of knowledge. Distribution by "macro" technological class

	Electrical Eng	Instruments	Chemicals & Pharmaceuticals	Process Engineering	Mechanical Engineering	Total
Laboratories	1.36 (1.75)	1.77 (1.88)	1.73 (1.85)	1.27 (1.70)	1.03 (1.56)	1.35 (1.74)
Scientific literature	2.64 (1.82)	2.84 (1.81)	3.66 (1.50)	2.42 (1.90)	1.82 (1.81)	2.55 (1.89)
Conferences	1.89 (1.77)	1.95 (1.77)	1.91 (1.68)	1.55 (1.71)	1.41 (1.66)	1.67 (1.72)
Patents	2.22 (1.78)	2.36 (1.86)	3.46 (1.66)	2.66 (1.92)	2.30 (1.92)	2.60 (1.90)
Users	2.72 (1.91)	2.84 (1.98)	2.25 (2.00)	3.15 (1.92)	3.16 (1.94)	2.88 (1.98)
Suppliers	1.33 (1.64)	1.56 (1.73)	1.20 (1.52)	1.62 (1.75)	1.82 (1.84)	1.55 (1.73)
Competitors	2.20 (1.80)	2.02 (1.82)	1.98 (1.85)	2.15 (1.91)	2.28 (1.90)	2.15 (1.87)

Note: standard deviations in parenthesis

Table 3.32 breaks down the "macro" technological classes into 30 "micro" technological classes. In most of these classes the ranking of the sources of knowledge reproduces those of the previous tables, with the users at the top of the ranking, followed by the scientific and patent literature, the competitors, the participation in technical conferences and workshops, and the interaction with the suppliers. The knowledge provided by the university and non-university research laboratories is at the bottom of the ranking in most of the "micro" technological classes. There are, however, a few exceptions. There are, for examples, technologies like Telecommunications, Semiconductors and Information Technology where the scientific literature and the participation in conferences and meetings are of primary importance as sources of knowledge for developing the patent. There are sectors like Optics, Organic fine chemistry, Macromolecular Chemistry and Polymers, Pharmaceuticals and Cosmetics, Materials and Metallurgy, Food Chemistry, and Chemical and Petrol industry where the scientific and patent literature is the most important source of knowledge amongst those listed in Table 3.32. Finally, while the university and non-university research laboratories are the least important source of knowledge in the vast majority of the "micro" classes, in Biotechnology they rank first together with the scientific literature.

Table 3.32 Importance of different sources of knowledge. Distribution by "micro" technological class

ISI Technological Classes	Laboratories	Scientific literature	Conferences	Patents	Users	Suppliers	Competitors
Electrical Devices, Electrical Eng. & Electrical Energy	1.21 (1.67)	2.26 (1.82)	1.56 (1.68)	2.42 (1.83)	3.01 (1.87)	1.61 (1.73)	2.46 (1.82)
Audio-visual Technology	1.35(1.75)	2.68 (1.79)	1.81 (1.78)	2.29 (1.81)	2.78 (1.91)	1.16 (1.58)	2.21 (1.80)
Telecommunications	1.44 (1.78)	2.99 (1.73)	2.30 (1.78)	1.86 (1.63)	2.26 (1.87)	1.03 (1.50)	1.91 (1.69)
Information Technology	1.64 (1.90)	3.02 (1.72)	2.21 (1.77)	1.91 (1.71)	2.58 (1.92)	1.10 (1.49)	1.83 (1.78)
Semiconductors	1.59 (1.79)	3.38 (1.66)	2.51 (1.96)	2.51 (1.74)	2.16 (1.88)	1.02 (1.42)	2.06 (1.80)
Optics	1.76 (1.75)	3.10 (1.70)	2.19 (1.68)	2.68 (1.85)	2.35 (2.03)	1.53 (1.60)	2.40 (1.78)
Analysis, Measurement, & Control Technology	1.78 (1.90)	2.79 (1.77)	1.88 (1.74)	2.18 (1.80)	2.91 (1.95)	1.45 (1.72)	1.87 (1.79)
Medical Technology	1.76 (1.92)	2.85 (1.91)	1.91 (1.85)	2.69 (1.97)	3.10 (1.94)	1.74 (1.79)	2.20 (1.86)
Organic Fine Chemistry	1.72 (1.88)	3.96 (1.34)	1.89 (1.70)	3.69 (1.56)	1.70 (1.88)	0.79 (1.22)	2.07 (1.90)
Chemistry & Polymers	1.56 (1.72)	3.53 (1.45)	1.97 (1.60)	3.72 (1.46)	2.78 (1.93)	1.46 (1.59)	2.11 (1.82)
Pharmaceuticals & Cosmetics	1.92 (1.94)	3.84 (1.44)	1.99 (1.77)	3.01 (1.84)	1.71 (1.90)	1.36 (1.66)	1.86 (1.93)
Biotechnology	3.10 (1.96)	3.84 (1.52)	2.44 (1.72)	2.43 (1.90)	1.76 (1.86)	1.06 (1.40)	1.69 (1.73)
Materials & Metallurgy	1.87 (1.91)	3.44 (1.62)	2.10 (1.85)	3.09 (1.75	2.87 (2.01)	1.29 (1.56)	2.09 (1.90)
Agriculture, & Food Chemistry	2.00 (1.96)	2.85 (1.87)	1.50 (1.62)	2.39 (1.92)	2.20 (2.00)	1.48 (1.63)	1.41 (1.62)
Chemical & Petrol Industry, Basic Materials Chemistry	1.48 (1.73)	3.46 (1.54)	1.85 (1.66)	3.54 (1.58)	2.88 (2.00)	1.39 (1.64)	1.95 (1.85)
Chemical Engineering	1.47 (1.90)	2.42 (1.87)	1.59 (1.72)	2.68 (1.90)	2.92 (1.98)	1.47 (1.75)	2.29 (1.92)
Surface Technology & Coating	1.75 (1.91)	3.28 (1.75)	2.07 (1.81)	3.15 (1.83)	3.00 (1.98)	1.45 (1.71)	2.05 (1.99)
Materials Processing, Textiles & Paper	1.09 (1.61)	2.49 (1.89)	1.43 (1.69)	2.73 (1.96)	3.20 (1.87)	1.76 (1.82)	2.11 (1.90)
Thermal Processes & Apparatus	1.49 (1.74)	2.21 (1.82)	1.64 (1.64)	2.52 (1.86)	3.14 (1.95)	1.79 (1.84)	2.08 (1.82)
Environmental Technology	1.94 (1.95)	3.06 (1.83)	1.97 (1.68)	2.55 (1.85)	2.85 (1.92)	1.32 (1.65)	1.76 (1.77)
Machine Tools	1.10 (1.60)	2.06 (1.88)	1.52 (1.69)	2.30 (1.87)	3.24 (1.88)	1.77 (1.79)	2.15 (1.81)
Engines, Pumps & Turbines	1.01 (1.55)	2.14 (1.81)	1.60 (1.74)	2.35 (1.88)	2.63 (1.99)	1.59 (1.79)	2.19 (1.86)
Mechanical Elements	1.07 (1.51)	1.97 (1.76)	1.45 (1.61)	2.40 (1.88)	3.32 (1.87)	1.91 (1.75)	2.41 (1.88)
Handling & Printing	0.82 (1.34)	1.77 (1.79)	1.30 (1.62)	2.42 (1.95)	3.36 (1.88)	1.76 (1.79)	2.25 (1.93)
Agricultural & Food Processing, Machinery & Apparatus	1.19 (1.51)	1.78 (1.73)	1.12 (1.41)	2.30 (1.90)	3.34 (1.88)	1.84 (1.77)	2.17 (1.86)
Transport	0.99 (1.51)	1.79 (1.75)	1.54 (1.69)	2.23 (1.91)	3.20 (1.88)	1.94 (1.83)	2.35 (1.89)
Nuclear Engineering	1.90 (1.97)	2.46 (2.13)	2.02 (1.98)	1.56 (1.67)	2.61 (2.13)	2.05 (1.99)	1.46 (1.67)
Space Technology Weapons	1.13 (1.71)	2.29 (1.85)	1.45 (1.80)	2.61 (1.91)	2.95 (2.06)	1.29 (1.59)	1.98 (1.86)
Consumer Goods & Equipment	0.79 (1.39)	1.42 (1.72)	1.09 (1.53)	2.29 (1.96)	2.98 (2.07)	1.77 (1.90)	2.28 (1.97)
Civil Eng., Building & Mining	1.07 (1.66)	1.53 (1.86)	1.19 (1.67)	2.17 (2.05)	3.48 (1.88)	1.91 (1.92)	2.38 (2.01)
Total	1.35 (1.74)	2.55 (1.89)	1.67 (1.72)	2.60 (1.90)	2.88 (1.98)	1.55 (1.73)	2.15 (1.87)

Note: standard deviations in parenthesis

Table 3.33 looks at the importance of different sources of knowledge for different types of inventors' employers. The users are the most important source of knowledge for the inventors employed in large, medium and small companies. However, when the inventors belong to public research institutions and universities, the scientific literature and the other research laboratories are the most important sources of knowledge amongst those listed in Table 3.33. This might be related to the more basic and general nature of the research performed by these institutions. The participation in conferences and meetings ranks third, followed by the patent literature. The users, the competitors and the suppliers are at the bottom of the ranking. In private research laboratories the ranking is similar to the latter, while the inventors affiliated to "other" government laboratories rank the sources of knowledge similar to those employed by private companies.

Table 3.33 Importance of different sources of knowledge. Distribution by type of inventors' employer

	Large companies	Medium sized companies	Small companies	Private Research Institutions	Public Research Institutions	Universities	Other Governm. Institutions	Others	Total
Laboratories	1.24 (1.63)	1.09 (1.57)	1.15 (1.67)	1.94 (1.95)	3.39 (1.88)	3.95 (1.61)	1.50 (1.95)	1.25 (1.81)	1.35 (1.74)
Scientific literature	2.64 (1.84)	2.06 (1.86)	1.96 (1.91)	3.80 (1.47)	3.42 (1.72)	3.80 (1.59)	1.71 (2.13)	2.09 (2.08)	2.56 (1.88)
Conferences	1.77 (1.72)	1.27 (1.59)	1.16 (1.58)	1.97 (1.90)	2.45 (1.83)	2.42 (1.83)	2.14 (2.18)	1.36 (1.84)	1.68 (1.72)
Patents	2.75 (1.86)	2.37 (1.96)	2.14 (1.97)	2.35 (2.01)	2.44 (1.82)	2.30 (1.87)	2.21 (1.97)	2.13 (1.93)	2.60 (1.90)
Users	2.87 (1.96)	3.25 (1.90)	3.12 (2.01)	2.49 (1.89)	2.11 (1.92)	1.80 (1.91)	3.00 (2.08)	2.51 (2.22)	2.88 (1.98)
Suppliers	1.55 (1.72)	1.74 (1.76)	1.66 (1.86)	1.63 (1.76)	0.94 (1.39)	0.96 (1.32)	1.86 (1.88)	1.51 (1.94)	1.55 (1.73)
Competitors	2.26 (1.86)	2.19 (1.89)	1.95 (1.92)	1.58 (1.87)	1.56 (1.69)	1.31 (1.62)	1.14 (1.79)	1.51 (1.80)	2.16 (1.87)

Note: standard deviations in parenthesis

Annex A III.4 adds two tables on the use of different sources of knowledge when the patents' applicants are located in one country as compared to the case in which they are located in more than one country, and when the applicants have European origins vs. non-European origins.

4. The EPO Patent Explosion – Some Descriptive Statistics

This part of the report examines the development of the number of EPO applications of time, by country as well as by broad technology areas and the most probable economic sector to use. This is done to document the explosion of the use of the European patent system in the last twenty years where the increase in the number of patent application is even stronger as in the increase in the number of patent applications to the US patent and trademark office which induced the academic and policy discussion about the recent surge in patenting.[10] [11] To lay the ground for the discussion on possible change in the (economic) value of patents this chapter documents the recent trends in patenting at the EPO. Hence these descriptive analyses might contribute to sorting out some explanations and highlight some facts which help pointing out direction where reasons for the recent surge in EPO patenting might be found.

4.1 The Data Source

The ZEW constructed a data set based on the European Patent Bulletin. The Bulletin contains bibliographic data as well as data concerning the legal situation of European patent applications and patents as laid down in Rule 92 EPC. By March 2005 about 1.4 million patent applications were available. The observations range from priority years 1977 to 2002. There are a publicity lag and administrative lags of creating the data base. Applications at the EPO through the PCT applications route are also included. Because of the long period of examination and the physical distances between the PTO patent offices these patents enter the data base with a time lag of about 2 years. Because of these time lags reliable information are available for priority years from 1978 to 2001. Also we admit that not all patents with priority year 2001 are included in this data base right now. Hence, we slightly underestimate the growth in patenting in 2001. However, it is clear from aggregated data published by the patent office that the growth rate observed in the nineties no longer prevails in more recent years.

Variables extracted from Bulletin are the dates of the application process (Priority date, application date at EPO, date of application for examination, grant date) as well as information about possible opposition and the opposing company or person, withdrawals, revocations, and other late status information, such as renewal payments. For the purpose of this project we extracted detailed information about the applicants and inventor and calculated some descriptive statistics.

Through out the analyses we use the following conventions:

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[10] Some of the increase may be attributed to an substitution of various application to one or more national offices in EU. The bulk of this reason for the increase in EPO patenting is probably occurring throughout the eighties. But we should be aware that this substitution still might have an effect also in the nineties.

[11] See Kortum and Lerner (1999) as an early reference for his still ongoing debate.

- The technological field of a patent is defined on the basis of the main IPC code.
- "Nationality" of a patent is determined by the address of the first inventor.[12]
- We use the priority data as the time stamp because the priority date is closest to the date of invention and hence to the decision to apply for patent protection or not.

Technology areas are defined quite broadly as patents primarily belonging the five areas "Chemical technologies", "Drugs and Health", "Electronics, Communication and Electrical Engineering", "Mechanical technology" and "Others". This broad classification of technology areas is widely used in the research in patenting (see e.g. Lanjouw and Schankerman 2001, Hall 2004, Kaiser et al. 2005). In order to allow for a more detailed and market based views we implemented the correspondence of patent classification and economic sector classification recent developed by Schmoch et al. (2003) which distinguish 44 different economic sectors based on the NACE classes. The use of this more detailed classification is limited to the analyses of large countries resp. country aggregates. It seems not useful to implement the more detail sector classification when looking at smaller countries or the new member states because the lower number of patent application will immediately the analyses might be biases to a small numbers problem.

4.2 Overall trends in EPO applications

First we start with examining the number of EPO applications overall as well as by the technology class for the large patenting countries resp. different aggregates of EU member states. Here we distinguish EU25, EU15 and the new member states (NMS). Figure 1 documents the rise in the number of patent applications at the EPO. We start in 1985 to avoid that the picture is too much influenced by the initial period of transition from pure national European patents systems to the regional EU patent system. From detailed analyses of major EU countries one can conclude that the first phase of this transition ended by the mid eighties.

Figure 4.1 and Figure 4.2 shows that the rise in the use of the EPO system is clearly visible in all country groups not matter whether we determine nationality at the inventor as well as at the applicant level. Even when restricting our view on the nineties and compare the increase to the US patent system the rise in EPO patenting still outperforms the rise in the number of USPTO applications. Both figures also show that EU15 (EU25) is the single most important applicant to the EPO followed by the USA and Japan. However, we should avoid to look at this as an reliable indicator for the international production of technology because the so called home advantage lead to a higher probability of EU inventions to be applied for at the EPO than in the case of the same invention made in the USA or Japan.

[12] We also worked with other possible conventions to determine the nationality of patents for counting applications i.e. random selection of one of the inventors, fractional counting, country of the first applicant. However, this does not materially alter our conclusions and hence we opted for the easiest and widespread methods.

Both figures show a decline of patenting in the early nineties for EU15 and EU25 aggregates which is mainly due to a slow down in patenting in major EU economies. Also, the number of patent application for Japanese invention is declining in this period. The slow-down is much less visible for the USA. In this period the number of patent applications from the New Member States unstuck dramatically. This is even more visible when looking at patent applicants instead of inventors.

Figure 4.1 Development of EPO Patent Application By Inventor Country

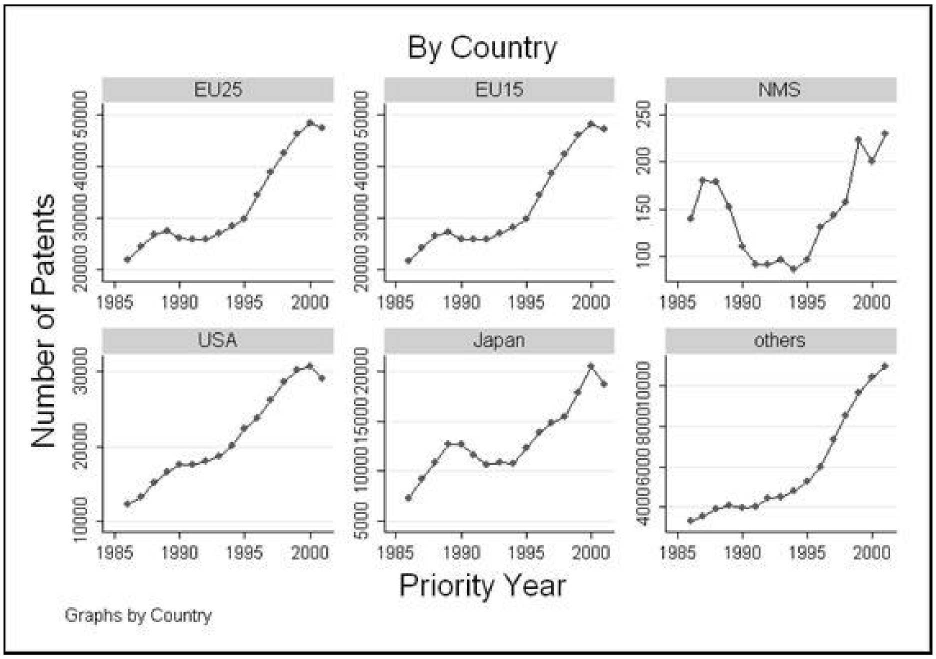
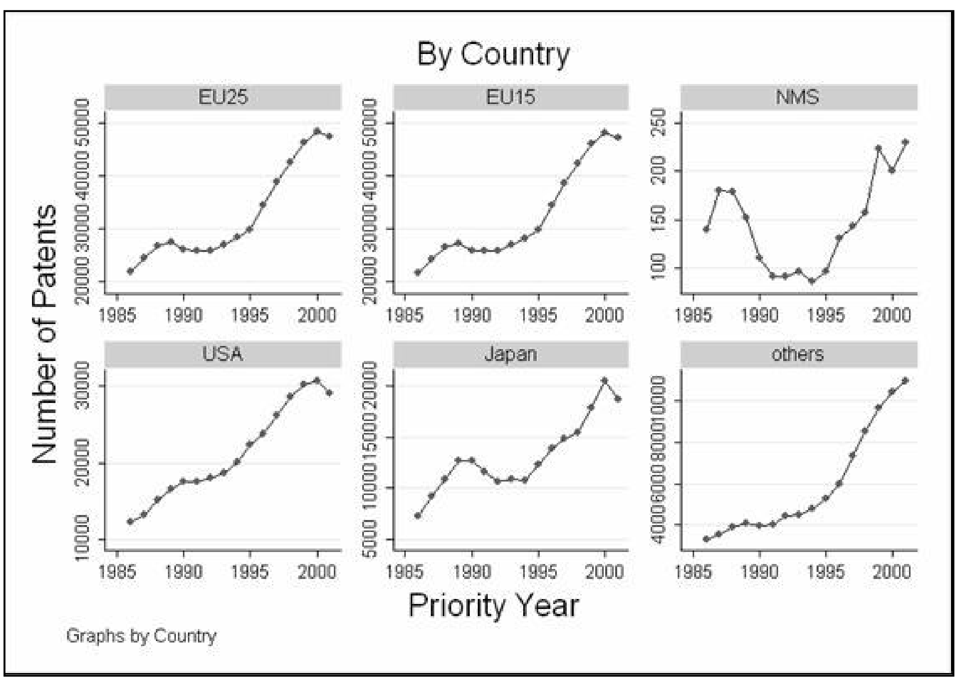


Figure 4.2 Development of EPO Patent Application By Applicant Country



In Figures 4.3 to 4.7 the same calculations by technology areas are presented. It is visible that the time series development of the number of patent application by country holds distinct technology specific patterns. So, in the field of “Drugs and Health” the early nineties slow down is less visible than in “Chemicals” or more in “Mechanical Technologies” or “Other technologies” in the case of the EU15, EU25 and the US where in the case of Japan the reduction in the number of patent application is most notable in “Chemistry” and “Health and Drugs”. The break down by technologies also highlights the rise in the importance of “Health and Drugs” as well as “Electronics, etc.” as the most dynamic fields of inventive activity.

Table 4.1 gives some indication on the use of the EPO system at the detailed country level. In order to avoid as small number bias for some smaller countries this league table is based on the sum of patent application of 1996-2002. Not surprising this table shows that within the EU Germany, France, UK and Italy are the larger countries in terms of the number of patent applications. Table 2 also provides a rough picture of technological specialization. When comparing the country shares we note that the ranking of countries might by different even when looking at broad areas of technology. E.g. one can immediately see from the table that Germany is dominating in mechanical technologies and much less stronger in “Drugs and Health”. For the USA the opposite specialization can be found. Similarly, Japan is specialized in “Electronics, etc.” and relatively weaker in “Drugs and Health”. Table 2 also highlights the low level of technological invention in the New Member States.

Figure 4.3 Development of EPO Patent Application by Broad Technology Areas - Chemicals

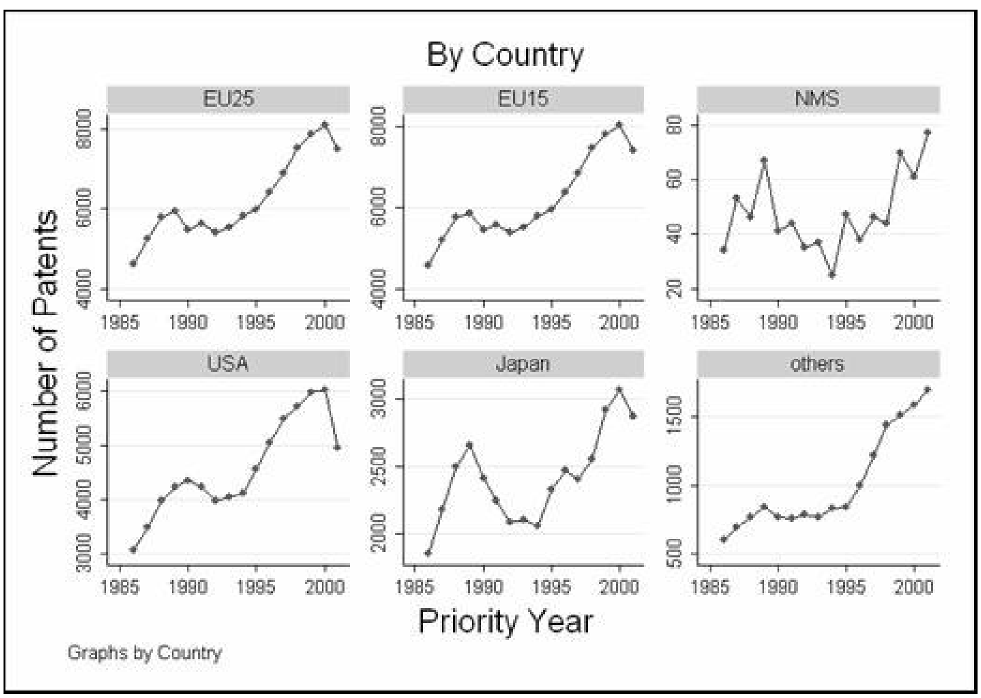


Figure 4.4 Development of EPO Patent Application by Broad Technology Areas - Health and Drugs

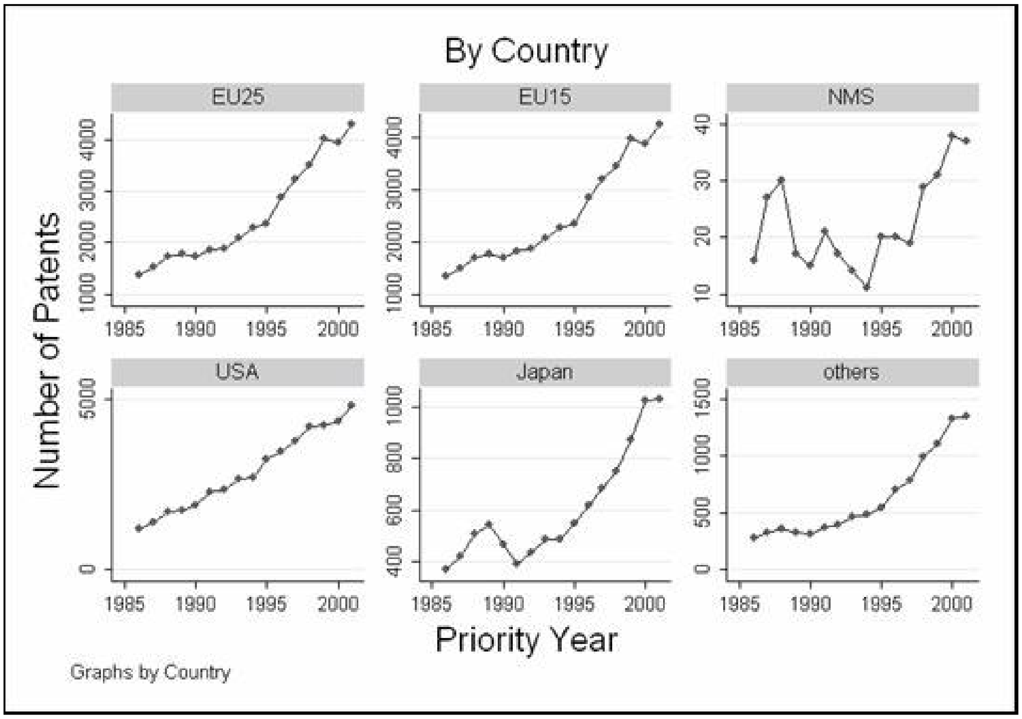


Figure 4.5 Development of EPO Patent Application by Broad Technology Areas - Electronics, Communication and Electrical Engineering

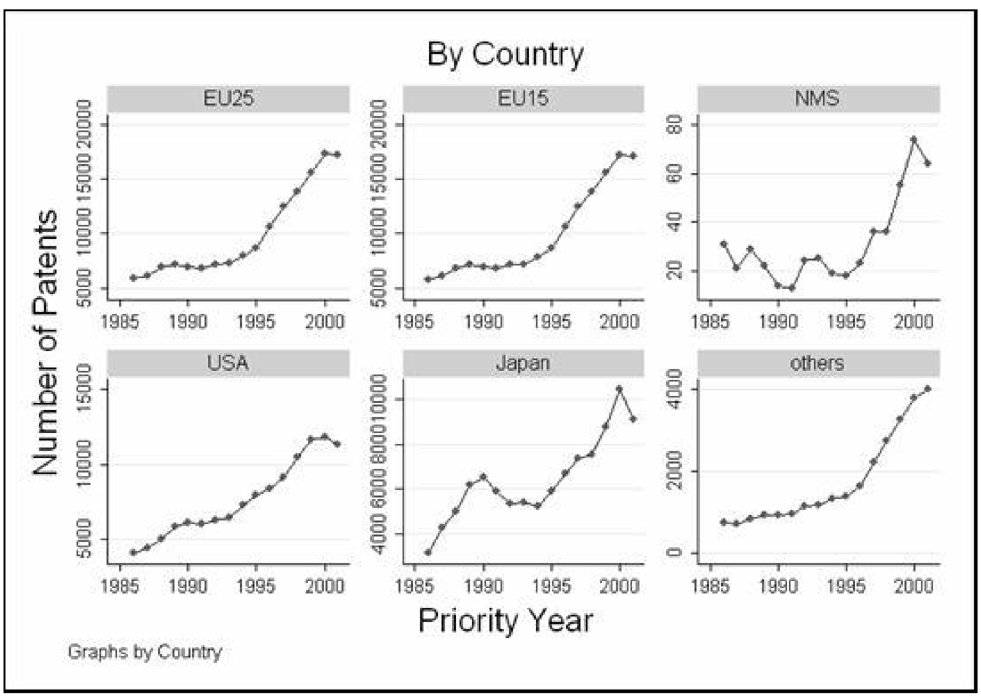


Figure 4.6 Development of EPO Patent Application by Broad Technology Areas - Mechanical Technologies

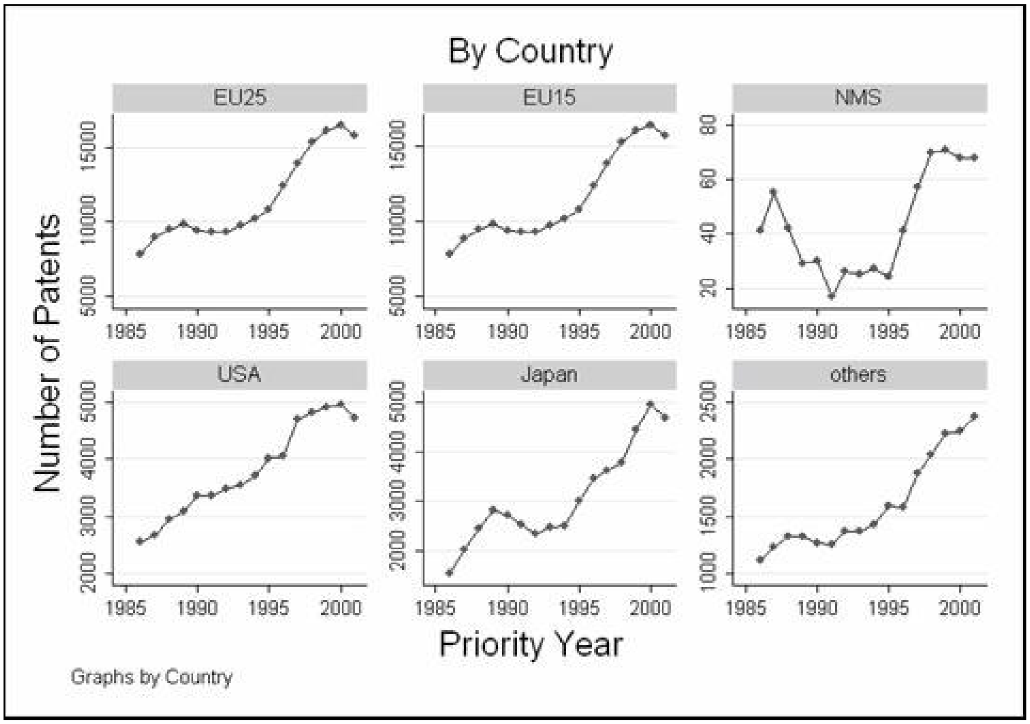


Figure 4.7 Development of EPO Patent Application by Broad Technology Areas -Other Technologies

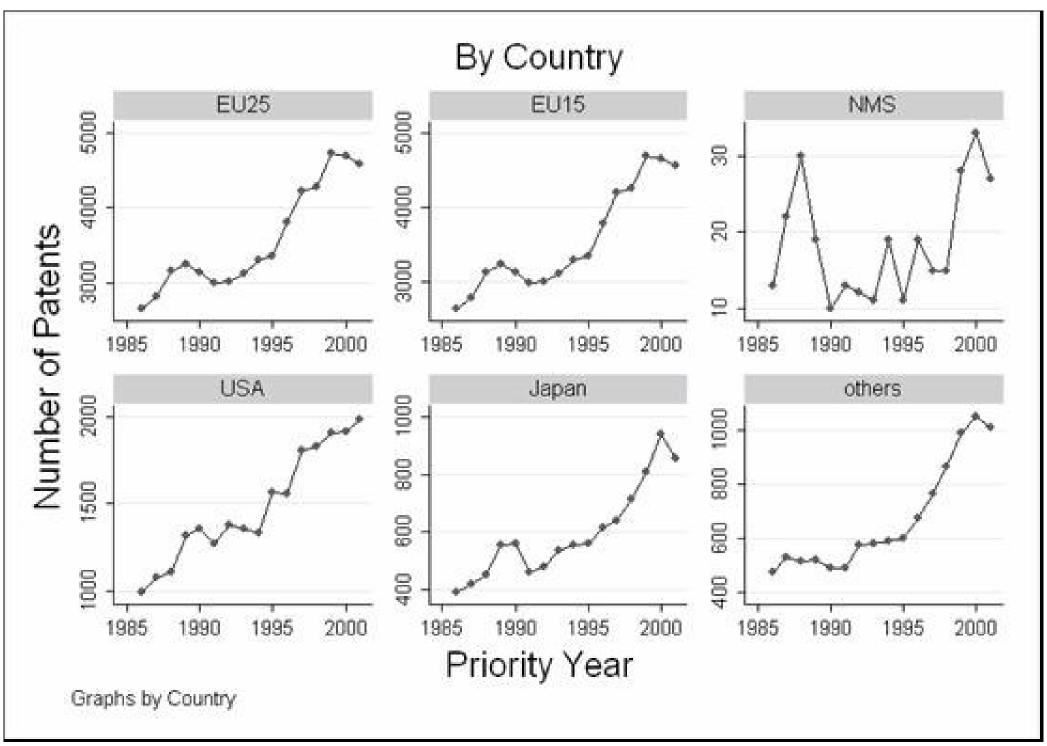
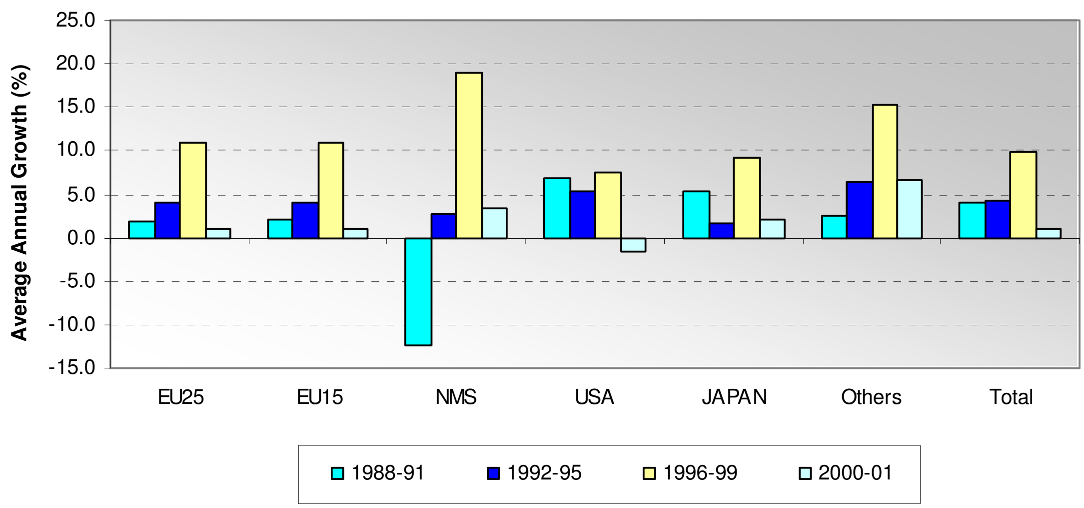


Table 4.1 Country Shares in Total EPO Application 1996-2002 by Technology Area (%)

Country	Chemicals	Drugs and Health	Electronics	Mechanical	Other	Total
EU25	43.559	37.811	40.161	58.222	55.994	46.644
EU15	43.229	37.510	40.028	57.979	55.702	46.417
USA	32.602	42.962	28.945	18.196	23.414	27.663
Germany	20.076	14.410	16.553	30.131	22.116	21.045
Japan	15.989	8.629	23.045	16.100	9.725	17.422
France	5.604	6.758	6.170	7.788	9.097	6.800
Great Britain	5.677	5.582	5.040	4.675	5.795	5.170
Italy	2.966	2.929	2.012	5.544	6.093	3.548
The Netherlands	2.267	1.509	3.920	2.037	3.832	2.877
Switzerland	2.021	2.363	1.771	2.762	3.679	2.294
Sweden	1.163	2.576	2.145	2.380	2.346	2.094
Canada	1.602	1.745	1.386	1.098	1.399	1.384
Finland	0.963	0.530	1.843	0.786	0.911	1.199
Belgium	2.104	0.782	0.783	1.097	1.292	1.141
South-Korea	0.957	0.595	1.481	0.543	0.683	0.985
Austria	0.675	0.613	0.566	1.698	1.443	0.964
Australia, NZ	0.841	1.395	0.651	0.966	1.284	0.895
Denmark	1.013	1.085	0.523	0.688	1.311	0.774
Israel	0.510	1.902	0.932	0.304	0.592	0.759
Spain	0.607	0.590	0.402	0.900	1.303	0.663
Other Asia	0.301	0.312	0.495	0.396	0.743	0.436
Norway	0.244	0.367	0.237	0.432	0.711	0.342
Other Europe	0.310	0.369	0.221	0.236	0.419	0.272
New Members	0.330	0.301	0.133	0.242	0.292	0.227
China (incl. HK)	0.207	0.220	0.240	0.165	0.411	0.226
Latin America	0.281	0.435	0.093	0.267	0.266	0.221
Ireland	0.099	0.355	0.189	0.134	0.245	0.179
Africa	0.111	0.199	0.094	0.152	0.347	0.143
India	0.365	0.344	0.058	0.023	0.085	0.133
Hungary	0.140	0.135	0.058	0.061	0.077	0.082
Luxemburg	0.045	0.010	0.028	0.140	0.032	0.060
Greece	0.031	0.104	0.032	0.069	0.087	0.053
Czech. Rep.	0.080	0.048	0.026	0.069	0.064	0.052
Poland	0.042	0.040	0.014	0.044	0.045	0.032
Slovenia	0.031	0.028	0.019	0.040	0.066	0.031
Portugal	0.037	0.031	0.012	0.047	0.043	0.030
Slovakia	0.021	0.009	0.004	0.010	0.015	0.010
Estonia	0.004	0.012	0.006	0.004	0.002	0.005
Cyprus	0.009	0.014	0.003	0.003	0.002	0.005
Malta	0.001	0.002	0.001	0.007	0.013	0.004
Latvia	0.001	0.009	0.001	0.003	0.004	0.003
Lithuania	0.002	0.002	0.001	0.001	0.004	0.002

Based on the inspection of the trends in overall patenting as well as the geo-political chance we also give the average annual compound growth rates by various periods. This is done in Figure 4.8. The overall trends in patenting come out even more clearly here. The figure shows an increasing momentum of EPO patenting until the year 2000 in EU25, EU15 as well as other countries. This momentum is especially notable for the New Member States. The growth rate in EU patenting outperforms US patenting in Europe in the second half of the nineties where as EU growth was much smaller before. For all country groups we see a strong decline in the growth of patenting at the EPO in 2000 and 2001. However, as mentioned earlier we have to note that this decline might overestimate the real decline in the growth rate of patenting due to the fact that the year 2001 is not covered equally as the early years by the most recent EPO bulletin data due to lags in publication of patent documents via the electronic EPO bulletin data.

Figure 4.8 Contribution to Overall Patent Growth by Country Technology Areas



4.3 Contributions by to Patent Explosion by Technology Areas and by Sector

In order to gain some more insights to technological shifts we also look at the contribution of areas of technologies as well as the probably sector of technology use to the overall growth in patenting.

Starting point for this descriptive analysis is a decomposition of the overall growth rate in line with the following formula

$$\Delta p_t^j = \sum_i \frac{s_{it}^j + s_{it-1}^j}{2} \Delta p_{it}^j$$

Where $\Delta p_t^j, \Delta p_{it}^j$ refer to the change in the number of patent application overall resp. in the technology area *i* in country *j* in the year *t*. The growth rate is calculated as first differences in logs. s_{it}^j is the share of technology area in total patenting in country *j* in the year *t*. Hence, this expression decomposes the actual growth in patenting into a weighted sum of the growth in each area of technology weighted by the share of each technology. The contribution of each technology area to the overall growth depends on both elements: the size of the technology area as well as the growth rate of patenting in this area.

The results of this composition can be found in Figures 4.9-4.12. The Figures tell us that the growth contribution differ strongly by areas of technology. The bulk of the growth in overall patenting can be traced back to the technology area “Electronics, communication, etc.”. This is not at all surprising given the technological dynamics in the nineties. But keep in mind that the large contribution of this field not only results from the significant momentum of patenting but also from the shear size of this area. This increase of the contribution is most notably in the EU15 and NMS whereas it roughly stays at a high level in the USA. Somewhat surprisingly is the steady decline of “Drugs and Health” as contributing factor in US patenting which is less visible from the charts presented above. The least contribution in case of the EU25 and EU15 results from patenting in “Chemicals” and “Other technologies”.

Figure 4.9 Contribution to Overall Patent Growth by Technology Areas – Drugs and Health

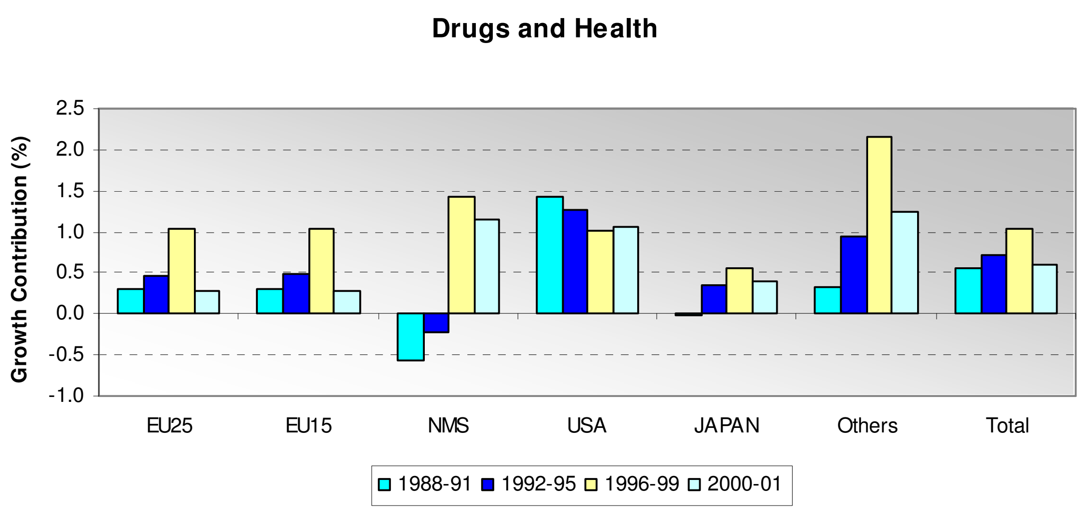


Figure 4.10 Contribution to Overall Patent Growth by Country Technology Areas – Electronics, Communication, Electrical Engineering

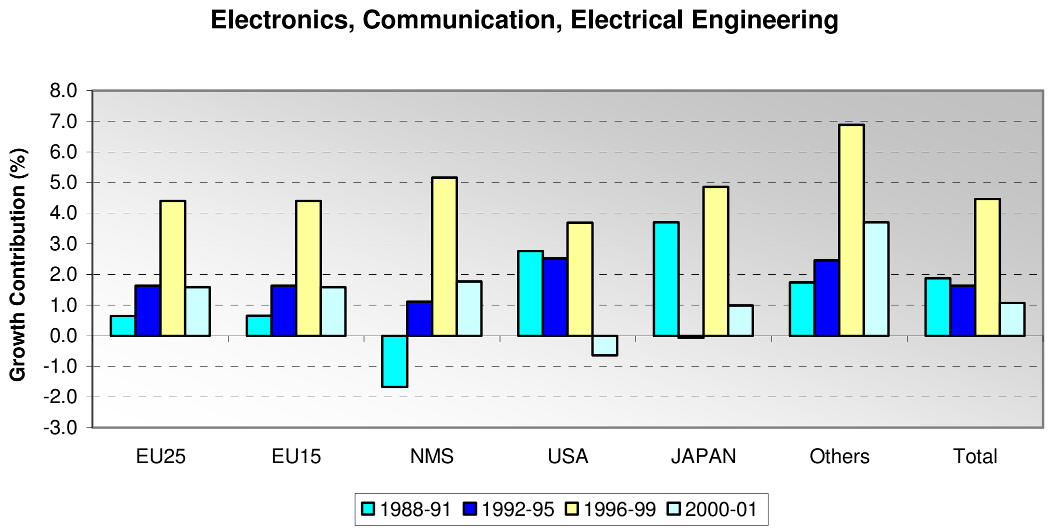


Figure 4.11 Contribution to Overall Patent Growth by Country Technology Areas – Mechanical Technologies

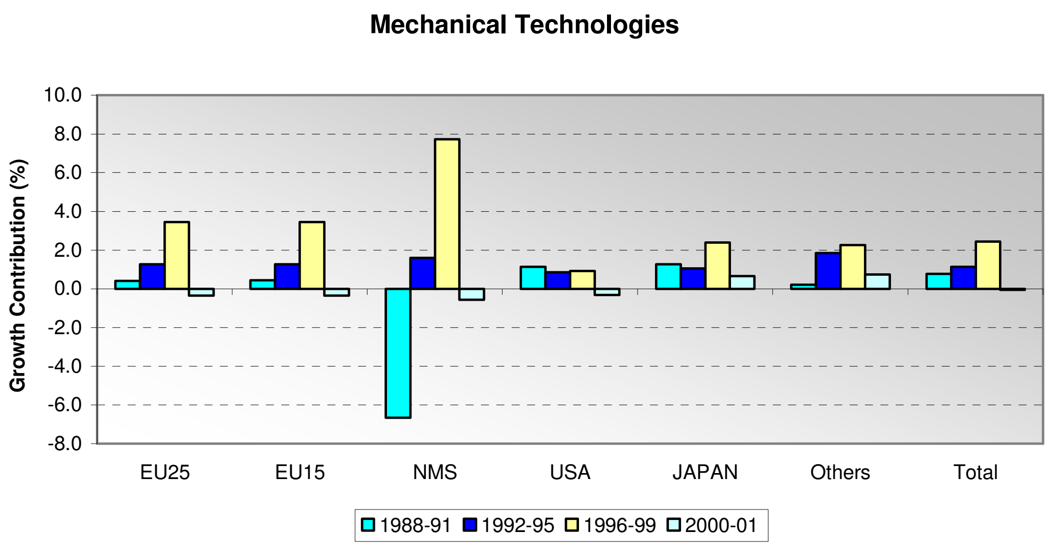
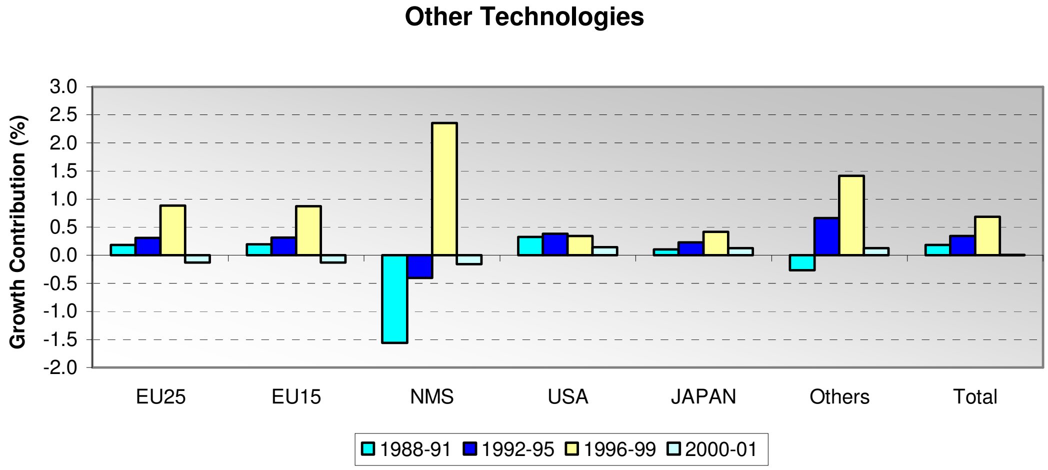


Figure 4.12 Contribution to Overall Patent Growth by Country Technology Areas – Other Technologies



A deeper insight into the technological dynamic is gained when looking at the much more disaggregated level of potential use industries. The results are reported in Table 4.2. We apply the above decomposition formula at the level of industry. To enhance the readability the contribution of a sector is expressed as per cent of the overall patent growth.

Given the small number of patent application of the New Member States this analysis can only be conducted at the EU25 level. The results of the decomposition of overall patent growth by economic sector yield an even more impressive picture of the importance of the information technology for the dynamics of inventive activity in the last 15 years. In addition, the technological differences between countries are even more pronounced at the industry level than at the level of broad technological areas.

First of all, communication technology delivers the largest contribution of the growth of patenting in Europe in the last 15 years. The importance of IT is underlined also by the fact that computing and office machines is ranked three over the whole period and its weight is even more increasing in the nineties. In addition, some other sectors strongly linked to the IT sector like electronic components, audio visible electrical equipment, and industrial process control are place in the top quarter of the table. In the case of the USA the leading role is played by the pharmaceutical sector. In addition, medical equipment also plays an important role when looking at the patent explosion. In addition to telecom and IT, the automotive industry is a main driver of invention activities are mirrored in EPO patent statistics. However, automotive industry is especially strong in Europe and Japan whereas its contribution to US patenting is much smaller.

Table 4.2 Contribution to Total Patent Growth by Sector (in %) – sorted by size of sector contribution to patent growth

Sector	EU25			USA			Japan			Others			Total		
	1992-1995	1996-1999	2000-2001	1992-1995	1996-1999	2000-2001	1992-1995	1996-1999	2000-2001	1992-1995	1996-1999	2000-2001	1992-1995	1996-1999	2000-2001
Signal transmission, telecom	25.98	13.41	14.78	15.33	16.75	12.64	-9.15	15.86	12.34	12.20	14.23	15.98	23.27	14.68	14.06
Pharmaceuticals	13.04	9.47	12.91	18.64	22.54	16.42	9.68	5.20	5.66	19.71	14.85	15.63	18.21	12.59	12.18
Office maschinery, computers	10.50	8.22	18.44	12.26	11.55	29.27	29.23	12.35	14.12	13.15	13.13	17.49	8.73	10.19	18.92
Medical equipment	11.04	4.83	3.96	18.89	9.05	15.51	1.79	2.95	5.27	8.72	8.15	7.68	17.17	5.93	6.70
Motor vehicles	4.18	10.55	9.61	4.31	2.67	4.18	3.29	9.63	10.42	5.16	1.80	1.30	4.58	7.55	7.58
Television, radio, audiovisual electr.	2.60	1.79	5.35	7.11	2.86	1.26	-4.57	3.33	2.51	7.80	2.20	2.45	7.48	2.33	3.54
Measuring instruments	-2.10	4.28	6.23	1.33	4.68	6.87	8.77	3.42	5.57	1.96	4.11	4.32	-1.22	4.23	5.86
Energy maschinery	1.95	3.33	4.22	0.73	1.66	1.92	0.59	5.32	4.68	3.66	1.46	1.75	1.71	3.03	3.56
Rubber and plastics products	6.79	2.81	2.38	2.19	1.31	1.39	0.88	1.65	1.29	1.40	2.44	1.57	4.08	2.22	1.83
Fabricated metal products	6.17	3.87	0.17	1.59	1.27	1.34	1.43	1.05	0.73	2.06	2.23	1.65	3.48	2.63	0.73
Non-specific purpose maschinery	2.48	2.29	1.64	1.52	1.22	0.45	-4.45	2.35	2.55	2.34	2.47	1.77	3.07	2.05	1.69
Domestic appliances	5.94	2.73	1.41	0.99	0.79	0.86	2.22	1.36	1.21	2.72	2.23	2.80	2.99	1.99	1.51
Optical instruments	0.14	1.49	2.74	1.87	2.18	4.49	1.92	2.75	3.16	2.68	2.19	2.38	1.32	1.93	3.06
Furniture, consumer goods	2.84	1.70	0.86	1.95	1.19	2.36	-2.86	1.36	2.05	0.73	2.72	2.04	2.94	1.63	1.57
Electronic components	-2.28	3.71	3.46	5.40	2.63	5.21	26.47	7.43	2.77	3.24	2.34	4.14	-1.65	3.87	3.68
Accumulators, battery	0.12	0.53	1.24	0.92	1.13	2.04	-6.61	3.03	3.11	1.83	0.55	1.26	2.05	1.06	1.82
Electrical distribution, wire, cable	3.78	2.00	-1.07	0.94	0.42	-2.65	-7.86	2.52	1.61	1.53	0.56	0.46	3.66	1.54	-0.42
Non-metallic mineral products	4.83	1.64	1.97	0.17	1.38	1.83	8.00	2.31	1.94	2.02	1.70	0.18	0.92	1.68	1.64
Electric motors, generators, transformers	2.69	0.91	0.50	0.60	0.19	1.16	-1.41	0.91	2.68	1.40	0.71	0.54	1.90	0.71	1.13
Other electrical equipment	2.15	1.30	0.05	0.29	0.34	0.12	-4.23	0.48	1.36	2.02	0.83	1.35	2.08	0.89	0.59
Special purpose maschinery	-2.23	5.50	-0.39	3.67	3.42	-3.58	7.10	2.71	2.67	-7.59	2.82	2.25	-1.07	4.27	0.28
Other transport equipment	0.75	1.00	0.79	0.64	0.77	0.31	-0.65	0.84	0.81	3.70	0.43	0.29	1.41	0.86	0.64
Soaps, detergents	5.39	0.59	-1.07	1.32	0.73	-2.02	0.59	0.42	-0.27	0.71	0.22	0.09	2.93	0.56	-0.84
Machine tools	-2.65	1.91	2.72	0.90	0.74	1.06	1.53	2.54	1.63	-2.65	1.34	0.90	-1.17	1.66	1.90
Food, beverages	0.69	0.67	0.77	0.79	0.31	0.74	1.14	0.51	0.34	1.71	1.79	1.04	0.84	0.68	0.71
Paper	2.69	0.18	-0.02	1.33	-0.06	0.56	1.37	0.11	0.42	0.28	0.33	-0.09	1.68	0.13	0.16
Pesticides, agro-chemicals	0.64	0.35	-0.05	0.77	0.95	-0.31	0.36	0.20	0.05	0.66	0.75	0.36	0.78	0.51	0.00
Lightening equipment	0.44	0.63	0.40	0.21	0.29	-0.57	-0.56	0.34	0.38	0.10	0.30	0.51	0.42	0.47	0.26
Agricultural and forestry maschinery	-5.12	1.49	0.60	0.06	0.82	0.51	-3.12	0.10	0.67	5.96	-0.27	0.40	-0.45	0.93	0.57
Wearing apparel	0.62	0.21	0.15	0.45	0.12	-0.20	-0.07	0.12	0.12	0.10	0.25	0.20	0.55	0.18	0.10
Petroleum products, nuclear fuel	1.10	0.17	0.29	-0.67	0.75	0.34	0.13	0.16	0.00	0.98	0.39	0.34	0.15	0.33	0.24
Industrial process control equipment	0.89	0.79	1.48	0.20	0.52	1.15	10.02	0.07	1.57	-0.93	0.72	0.56	-1.39	0.61	1.30
Textiles	-0.41	0.20	0.20	0.41	-0.11	0.58	-0.42	0.23	0.31	-0.35	0.12	0.02	0.11	0.12	0.26
Wood products	0.28	0.16	0.40	0.03	0.05	0.00	-0.54	0.04	-0.08	-0.07	0.12	0.03	0.21	0.11	0.16
Leather articles	0.70	0.08	0.02	-0.14	0.09	-0.11	-0.51	0.09	-0.03	-0.04	0.20	-0.01	0.26	0.10	-0.02
Watches, clocks	0.09	0.06	0.02	0.02	0.02	-0.02	-0.36	0.53	-0.13	-0.18	0.46	0.70	0.08	0.16	0.09
Man-made fibres	0.90	0.01	-0.04	-0.06	0.01	0.45	1.72	0.27	0.10	-0.04	0.10	0.03	0.00	0.06	0.08
Paints, varnishes	-0.22	0.02	-0.02	0.04	0.01	-0.04	0.04	0.03	-0.03	-0.01	0.09	0.02	-0.07	0.03	-0.02
Basic materials	-2.29	1.80	-0.16	-0.88	0.52	-0.21	3.62	0.99	1.57	1.29	2.31	-0.63	-1.87	1.41	0.17
Other chemicals	0.19	0.06	0.02	2.56	-0.47	0.19	10.05	-0.42	-0.32	-1.03	0.43	0.38	-0.26	-0.11	0.03
Tobacco products	-0.07	-0.01	0.07	-0.53	-0.02	0.12	-0.03	0.04	0.02	-0.48	0.04	0.10	-0.41	0.00	0.07
Weapons and ammunition	-1.58	0.17	0.09	0.16	0.06	-0.47	0.03	-0.01	0.00	-0.28	0.32	0.34	-0.57	0.13	0.03
Basic chemicals	-3.54	3.12	2.90	-8.32	4.70	-5.28	15.09	4.95	5.16	1.92	6.03	5.44	-8.85	4.10	2.57

5. CONCLUSIONS AND RESEARCH PLAN FOR LOT2

This Report provided detailed data and a comprehensive review of the literature on the economic value of patents. The Report moved along 4 Themes. For each of these Themes we analysed the background literature, and we provided descriptive statistics along with comments about the main patterns that emerged from the data.

The Report is composed of 5 Sections and 3 Annexes. Section 1 described the aim and the organisation of the Report. Section 2 presented the methodology employed in the survey of the literature and the database that we created on the surveyed publications. We collected the references (scientific papers, books, Reports, etc.) on various aspects of the direct and indirect effects of the patent system in Europe, US and other countries. Section 2 also summarised and discussed a representative part of the background literature. Annex II reports the data on the coverage of the literature by Theme, technologies, countries, type of inventors' organisation and type of contribution.

The analysis of the background literature helped us refine the plan for research in Lot 2 of this Project. Moreover, by summarising the main contributions on the four Themes of our study, the survey of the literature highlighted the main gaps in the existing literature that would need further investigation either from the theoretical and empirical point of view.

For example, most studies on the relationship between R&D and patenting focus on the impact of R&D on patenting activity, but not vice-versa. It is indeed the latter which needs to be analysed in more detail in order to evaluate the intended economic objective of the patent system. In particular, little work has been done on the relationship between the drivers of patent value (such as the characteristics of the litigation environment, and their changes over time) and the investment in innovative activity, firm performance, economic growth, and employment, and their changes over time. Longitudinal studies on this topic are missing, mainly because of the lack of comparable innovation surveys that are repeated over time.

Some contributions describe the casual link between the changes in the patent premium and R&D in a cross-section perspective for the US. However, the empirical evidence is missing for Europe. Moreover, this literature does not employ direct measures of the drivers of the premium afforded by the patent, and it does not provide strong policy guidance. Some other studies define the dynamic relationship between patenting or patent value and firm performance, but they do not distinguish between the impact of patent protection and the impact of innovation.

Few studies systematically quantify the social costs of patenting, in particular with reference to the social costs of patent-litigation activities. However, more information would be needed to evaluate whether patent quality changes significantly over time, and how these changes relate to the overall innovation and growth patterns. Similarly, it is not clear the extent to which the increasing strategic use of patents hinders or stimulates innovation.

A few studies have analysed the determinants of licensing and the development of markets for technologies as devices to increase the use of patents. However, theoretical and empirical studies on the extent and the determinants of the "unused" patents are scarce or inexistent. It would be crucial to fill this gap to derive policy suggestions on how to increase the use of property rights.

As far as the indirect effects of patents are concerned, there are some studies on spin-off firms from patented inventions by university scientists, especially for the US. There is not, however, systematic evidence on the formation of new firms from the patented inventions in the private sector, and in Europe or in countries other than the US.

Finally, although many contributions studied the relationship between patents and spillovers (mostly by means of patent citations), a few contributions, especially for Europe and the US, analysed the extent to which knowledge spillovers are conditioned by patent protection, and the causal link between such flows of information and firms' R&D productivity.

All in all, we found out that there is a strong need for further research on specific issues included in the Themes analysed in this Report. In particular the evidence is weak in some countries and regions (i.e. Europe and the New Member States), and in some large technological fields: there are technologies like mechanical engineering and electrical engineering in which about half of the EPO patents are classified, but that received very little attention in the literature.

Section 3 reported and commented on Tables and Figures of selected descriptive statistics based on the PatVal-EU dataset. This Section presented the main patterns that emerge from the data by NUTS2 regions (as classified by Eurostat), country, technological classes and applicant organisations.

The 4 Themes analysed in this Report are the following:

(A1) The value and social costs of patents. We described the distribution of the monetary value of the PatVal-EU innovations, and we confirmed that such distribution is skewed, with only few patents that yield large returns. We also analysed the private and social costs of the European patents. These statistics were reported by countries, European regions, applicant organisations, and technological classes.

(A2) The economic use of patents and the motives for patenting. We defined six possible uses of patents (i.e. internal use, licensing, cross-licensing, licensing & use, blocking competitors, and patents that are not used at all – i.e. "sleeping patents") and six motives for patenting (i.e. commercial exploitation, licensing, cross-licensing, prevention from imitation, blocking competitors, and reputation), and we analysed their distribution across countries, technologies and applicant organisations.

(B1) The creation of new businesses from the patented innovations. We reported the share of patents in the PatVal-EU database used to start-up a new firm, and we described the differences among the 6 EU countries, the "macro" and "micro" technological classes in which the patents are classified, the European regions, and the applicant organisations.

(B2) Collaboration, spillovers and the sources of knowledge in the innovation process. Many patents have multiple inventors, which suggests that the innovation activity is organised around teams of researchers. The vast majority of these co-inventors belong to the same organisation and are geographically close. Moreover, the most common source of knowledge in the innovation process is the interaction with the customers. University and non-university research is rarely used. These statistics were provided by European countries, regions, "macro" and "micro" technological classes and type of applicants' organisations.

Section 4 reported selected Tables of descriptive statistics on counts of EPO patent applications from 1986 to 2001, and provided trends over time and across technological classes. By showing aggregate data at the level of US, Japan, EU-15, EU-25 and New Member States, Section 4 provided preliminary insights on cross-country comparisons. An increase in the use of the European Patent System is visible in all the technological areas and in nearly most sectors of the economy. However, the momentum of the increase strongly differs by technological area and sector, probably reflecting differences in the technological dynamics. The differences in the momentum of the patent value might help explain the differentials in the dynamics of patenting in Europe. This is suggested by the fact that the dynamics of R&D inputs by sector differ from the dynamics of patenting. Further research is needed to study the relationship between the growth of patents and R&D.

The Annexes at the end of the report supplied additional information on: (1) the organisation of the dataset for the survey of the literature; (2) the coverage of the survey of the literature; (3) Tables of descriptive statistics produced by using the PatVal-EU dataset that complement the data presented in Section 3.

It is worth stressing that the analysis of the background literature and the empirical work with patent data performed in Lot 1 provided useful suggestions to guide the research in Lot 2. On the one hand, as noted above, they suggested that there are still many open problems and questions to be addressed, and they showed the gaps in the empirical literature. For instance, we found that an important gap in the literature concerns the impact of patenting activity -- and in particular the impact of specific characteristics of patents, applicants and invention processes -- on R&D. This will inspire the empirical models to be developed in Lot 2. On the other hand, the analysis of the data in Section 3 and Section 4 of Lot 1 provided a general base for guiding the empirical investigation in Lot 2, and the search for policy suggestions that are expected to arise from the results of the studies in Lot 2.

For example, the descriptive statistics pointed out that there are interesting differences across European countries and regions, technological classes, and types of inventors' employers (i.e. private firms vs. public organisations; companies vs. universities and other research institutions; large vs. small firms; domestic vs. foreign applicants) concerning the value and the cost of the European patents, their use, the formation of new firms, and the occurrence of spillovers and collaborations among inventors and institutions in the innovation process. More systematic empirical analysis is needed to explore these differences and their causes. More precisely, in order to identify the net effect of different factors on the variables of interest (i.e. the value of patents, the propensity to start a new company, etc.), we need to perform multiple correlation analyses based on specific econometric models.

Against this background, we plan to produce a series of scientific studies concerning the advantages and disadvantages of the patent system, and in particular the direct and indirect impact of patents on the economy and society. For each Theme we will develop aggregate econometric contributions and contributions at the level of specific countries, technological classes and inventors' employers. We will also integrate the datasets used in Lot 1 with additional data required for the specific purpose of the different studies. The remaining part of this Section presents a detailed research plan for Lot 2 in line with the original research project.

(A1) The Economic Value of Patents

The study of the economic value of patents will use several indicators of the importance of patents to proxy for their value, as suggested by the literature in Lot 1. We will use regression-based empirical models to estimate the economic value of patents.

Study A.1.1. The Value of Patents from Indirect Indicators

The contributions under this heading will study the value of patents by using indirect indicators, and they will develop through three empirical studies. The first one will employ indicators that have proven to be correlated with patent value such as the number of forward citations, the number of claims, the patent family size, and to some extent the occurrence of opposition procedures. These indicators will be used to develop an "importance index" of the patent rights. The importance index will then be linked to the monetary value of the patents by using the renewal information contained in the patent database. In so doing, this work will follow the methodology pioneered by Ariel Pakes and Mark Schankerman that we cited in Lot 1. The ensuing estimates of patent values can be assessed for different countries, regions, technological areas, and types of applicants.

The second analysis will focus on the private value of patents for the applicants. It will use the methodology proposed by Harhoff, Scherer, and Vopel (2003b, cited in Lot 1) to provide a direct assessment of the value of a patent right to the owner. The analysis can differentiate the applicants in the ZEW-EPO patent database into 3 categories: individual applicant, private enterprise, and public institution. This will be done by analysing the text in the patent document with the names of applicants. We will also take into account the administrative differences among the patent systems in Europe. For example, not all European Universities are allowed to own patents. In countries such as Sweden the Professors will be the applicants or the owner of the patents, whereas in other countries (e.g. Germany) the public institutions such as the Universities and Colleges apply for the patents. Apart from the assessment by applicant types, we will estimate the value of patents by country and technological class, and the results of the two studies will be compared to check for the robustness of the results.

The third analysis will look at the value of patents as proxied by the efforts undertaken by the assignees to legally enforce their patent rights. Harhoff and Reitzig (2004, cited in Lot 1) found that European patents that have been opposed and upheld either unchanged or amended are on average more valuable than the average patents. The private interests of the parties either in an opposition procedure or in a litigation case are related to the efforts that the parties undertake as proxied by the costs involved. We will produce case study evidence from data on patent litigations in Germany from 1993 to 1995. The estimated cost of enforcement (probability of litigation and average costs) will indicate the effort that an applicant undertakes to enforce his patent rights.

Study A.1.2. The Value of Patents from Survey Data

Our second study will rely on the measure of the economic value of patents gathered from the PatVal-EU survey, and it will combine this information with data provided by the Regio database on the European regions, and those on firm characteristics drawn from the Who Owns Whom and Amadeus databases.

In the PatVal-EU survey we asked the inventor to provide a quantitative estimate of the value of the patent that they contributed to invent by using a scale that goes from zero economic returns to "more than 300 million euros". We examined the distribution of the patent value in Lot 1. While we should be aware of the potential shortcomings of this measure, we believe that this is a fairly reliable measure of the economic value of patents. Moreover, it is the only available measure we know that bases the estimates of the value of the patent on the correct economic concept, viz. the expected value of its future stream of profits at the moment of grant. In other words, compared to other indicators of the value of patents, which rely on their importance (e.g. citations, claims), not only is this a direct measure, but it is also the only one that provides a monetary estimate of the value.

The empirical work will study the determinants of the economic value of the patent. It will use an ordered probit regression where the value intervals are the dependent variable. Our regressors are drawn from the PatVal-EU database and from other datasets to explore the impact of four sets of determinants: i) characteristics of the *organisation* in which the patent was developed; ii) characteristics of the *inventors*; iii) characteristics of the *patent*; iv) characteristics of the *location* in which the patent was developed.

To our knowledge, this is the first attempt that investigates the impact of such a comprehensive set of determinants on the value of patents. It also presents several novelties with respect to previous research on this issue. For example, by using the PatVal-EU data, we will assess the effect of factors that were ignored in previous studies like the inventors' characteristics (e.g. age, past productivity, educational degree). In addition, it will enable us to understand empirically the relative importance of different factors affecting the value of patents. For example, how important are the technological characteristics of patents in determining its value? That is, is patent value largely determined by the sector or type of technology, or are there differences depending on the individual inventor, the organisation or the location? How important are the inventors' characteristics vis-à-vis the type of applicant organisation? Do more valuable patents depend on "star" inventors, or are they explained mainly by organisational characteristics, like the greater resources provided by the large firms or the more creative atmosphere of the small firms? Interestingly enough, the latter situation suggests that shopping for talents would not be crucial for an organisation, as the proper organisational setting can turn most individuals with suitable characteristics into good inventors, while the opposite is true in the former case. Similarly, our analysis enables us to assess the relative importance of agglomeration economies, spillovers and local factors more generally.

Study A.1.3. The Monetary Value of Patents and the Use of Multiple Indicators

By using the PatVal-EU data we will provide an assessment of the monetary measure of value against alternative indicators. We will check the validity of our monetary measure in three ways. First, we will regress five traditional indicators of patent value on our value intervals, and our value intervals on the five indicators, along with technology, application year and country dummies as controls. In our second check, we will construct a patent value index using the same methodology and indicators employed by Lanjouw and Schankerman (2004). As they note, this index captures the combined effect of the underlying indicators. Finally, a third aspect of our patent value measure is that the individual inventors may not know about the value of the patent as much as the managers who are responsible for their development. The problem is probably not that severe in the case of the smaller firms or non-profit research labs, but it can be more serious in larger firms wherein the organisational distance between the inventor and the managers responsible for their development can be notable. In our survey there are 354 French patents whose value question was submitted to both the inventor and to a manager responsible for the development of the patent. On comparing the two distributions we will find out whether there is just a slight overestimate of the patent value by the inventors, or if this is a serious issue to deal with.

Study A.1.4. Value of Patents and Relationships with R&D

Our analysis of patent value cannot neglect the relationships between patents and R&D. We will employ a methodology similar to that of Bessen and Hunt (2004, cited in Lot 1). Based on a merge of patent and firm data we will estimate econometric models to determine the relationship between patents and R&D, and vice versa. We will estimate a patent production function and we will introduce a methodology to separate productivity effects in the invention process from behavioural effects that are also present in the patents – R&D relationship. The identification of both effects, which are intertwined in the study by Bessen and Hunt, rests on the introduction of the invention production equation, and an equation that models a firm's application decision.

Furthermore, by allowing for an impact of the patent system on R&D investment we will shed some light on the ability of the patent system to overcome the externality resulting from limited appropriability of R&D. If we find that patents have a negative impact on R&D this will give some hint on the social value of the patent system as the latter would fail to provide R&D incentive, which is the basic rationale for the patent system. In a first step this approach will be applied to EPO applications of firms in selected countries like Germany. The basic rationale for this is that Germany shows an even stronger increase in the patents to R&D ratio than the US. To do this we will combine data from the German Mannheim Innovation Survey with EPO data. In addition, we will not only use simple patent counts as indicators but also try quality-weighed patent counts. The weighing procedure will be developed during the project.

We will also try to collect similar data on R&D for other European countries in order to extend the coverage of this study. In particular we will also try to assess the impact of specific characteristics of the invention process drawn from the PatVal survey data on the incentives to invest in R&D.

(A2) The economic Use of Patents and the Potential for Enhancing It

The PatVal-EU dataset enabled us to obtain information on whether the patent in the sample was: i) used internally by the assignee for economic purposes; ii) licensed; iii) internally used and licensed; iv) left unused. We will develop empirical models that predict these choices. This will enable us to study the extent to which patents are exploited for economic purposes in Europe, and how they are used. We will also identify the characteristics of the unused patents, and the characteristics of the patents employed in the market for technology. Moreover, by using the estimates of the value of patents produced under the A1 Theme we can estimate the potential value of patents that are left unused. This can be aggregated at the level of countries or technological areas to provide an estimate of the under exploited value of patents. To our knowledge, this is one of the very first attempts to empirically estimate the extent of the potential economic value of unused patents.

Lot 1 produced a series of descriptive statistics on the share of patents in each of these categories by country, technological class, and type of applicant. In this study we will move one step further by exploring the determinants of these choices. We will then use our estimates using the PatVal-EU sample to draw inferences for the populations of patents. In particular, we are interested in estimating the value of the unused patents.

Study A.2.1. The Determinants of Licensing vs. other patent uses. An empirical investigation from European Survey Data

The last two decades have witnessed a variety of arrangements for the exchange of technologies. Especially in technology-based sectors, licensing has become a necessary means to exploit firm technology and to sustain their competitive advantage. This study will use the PatVal-EU data to present new empirical evidence on the determinants of the decision of firms to license a patented innovation. It will also use data provided by Who Owns Whom and Amadeus on firm characteristics. We expect that the probability to license a patent is positively influenced by the patent scope, and that it is greater for patents employing more "basic" knowledge. Small firms are expected to be more likely to license; when licensing, large firms are expected to be more likely to license non core technology. These results are consistent with a theoretical background that merges the transaction cost approach and the resource/capability based view of the firm.

The aim of this contribution will be to investigate the effect of different covariates on the probability that a patent is licensed. We will employ a multinomial logit specification that separates the effects of covariates on different patent fates, namely i) the patent was licensed ii) the patent was licensed and used internally by the owner; iii) the patent was only used internally by the owner and iv) the patent was not used. Since our data are both patent and firm level specific, and since there are repeated observations for the most patenting firms, we will control for firm heterogeneity.

This is an important contribution to the existing empirical literature on licensing for several reasons. First, notwithstanding the richness of the theoretical literature on licensing, the empirical evidence is still very scattered, mostly due to the limited availability of adequate data. So far, the empirical analysis on licensing was mostly centred on historical approaches and case studies in particular industries or on small sample studies. Only a few recent studies use extensive databases (i.e. Anand and Khanna, 2000; Fosfuri, 2004; Arora and Ceccagnoli, 2004). Our paper represents the first extensive analysis conducted on surveyed patent-level data. In our study the information on whether the patent has been licensed is available at the level of the single innovation. Another important advantage of our data is that they allow for the distinction on whether the patent has been only licensed, or it has been both licensed and used internally by the firm, or it was only used internally, or, finally, it was not used. This is a key information because we can estimate the different effects of our covariates on different behaviours of firms. Moreover, by using a large dataset, our empirical analysis can detect significant low magnitude effects on the probability of licensing when distinguishing between all the possible outcomes for a firm's patent. This allows us to assess more sharply the variables that play a significant major role on the probability of licensing.

Study A.2.2. On the use of patents: a quantitative analysis based on the PatVal-EU data

The goal of this work is closely related to the A.2.1. study. By using the PatVal-EU data together with data on firms drawn from Who Owns Whom, Amadeus and Delphion, it aims at uncovering the determinants of different uses of patents by the firms: internal use, non-use. It will also look at the determinants of the "non use" of patents: strategic (i.e. blocking) and sleeping patents.

Several recent papers have emphasised how important from a policy perspective is to understand if patents are actually used or left unused (Scotchmer, 1991; Mazzoleni and Nelson, 1998; Hall and Ziedonis, 2001; Ziedonis, 2004). One of the main concerns in the literature is that the increasing strength and effectiveness of patent protection may increase the propensity to patent, but it can reduce the actual use of the patents, especially by dominant firms. The social risk of unused patents is larger if patents have a broad scope, because they may block potential uses of the inventions for different applications by other actors, and they are not used by the patenting company. The empirical analysis on this issue is scarce. Our contribution will cover this gap.

Moreover, an important novelty of this work lies on the joint examination of the determinants of the patent uses, and the different motives for not using a patent (i.e. to block competitors vs. "sleeping" patents). By using the existing literature on the determinants of licensing, the markets for technology, the motivations to patent, and the advantages and drawbacks of the patent system, we will derive hypotheses on the factors that might explain the outcome of a patent. These determinants are: the patent scope, the breadth of patent protection, the linkage with science, the size of the firm, the availability of complementary assets, the competitive environment (spillovers from competitors or presence of innovation race), and the cost of projects. Country and technological controls will be included.

(B1) New Firm Creation and Employment

The PatVal-EU survey asks specifically to the interviewee whether the patent was used to create a new firm. Once again, descriptive statistics of this phenomenon by country, technological class, and type of applicant was performed in Lot 1. These statistics revealed that this is not a rare event, especially in some countries. We will produce empirical models that predict the creation of new firms from patented innovations. By using our estimates of the patent value we can also predict the value of the new firms based on intellectual property, with breakdowns by country and technological areas. The value of these firms, along with other characteristics, can then be used to predict the employment potential of these firms.

Study B.1.1. Firm creation and the value of patents

By using the PatVal-EU data, we will begin by running logit regressions with a dummy for whether the patent gave rise to a new firm or not. As principal covariates we will start with the usual set of inventor, region, organisation, and sector characteristics. We will then refine the analysis from the feedbacks coming from the actual empirical implementation of this study. We will assess the contribution of the patents that give rise to new firms in two ways.

First, we will infer the value of the patents that produced a new firm. To do so, we will use the characteristics of the patents to predict their probability of producing a new firm from the logit regression. We will then estimate the value of these patents from our analysis in *Study A1.2*. The product between the estimated value of the patent and its predicted probability of giving rise to a new firm will give an estimate of the value of the knowledge asset of the firms created from intellectual property. This is a lower bound of the value of the new firms. From the literature and from the relevant trade press we will look for estimates of the weight of the value of knowledge assets to the total value of start-ups or similar firms (possibly by country and sectors), and then infer the value of these firms.

Second, we will assess the employment potential of these firms. Again, from the literature and from the relevant trade press we will try to single out information in order to correlate the value of these firms with the size of their employment (possibly by country, sector, or other dimensions). This will then be used to estimate the total employment of firms created from intellectual property in Europe or by individual countries and technological areas.

Clearly, this kind of analysis requires a great deal of inferences from many sources. However, there is so little evidence on this very important issue that such inferences are nonetheless most informative. This contribution will provide important results about the indirect effects of the patent system on employment and competitiveness in different European regions. The direct effect of the patent system on employment is very difficult to detect empirically, but we think that entrepreneurship is a good way for exploring and assessing indirect effects on employment and regional advantage.

(B2) Knowledge Spillovers from Patents

The goal of this analysis is to assess the extent of the social benefits of patents produced by knowledge spillovers. As noted in Lot 1, this analysis is important as it can suggest that while the inherent rationale for patenting implies a reduction of the social ex-post output (as the patents grant a monopoly), their contribution to knowledge spillovers implies that such limitations on social welfare are in fact less severe. There is concern, however, that too many patents are applied with the sole scope of blocking rivals. If this is so, the social value of patents would be enhanced by limiting the number of patents that produce little spillovers. The analysis under this Theme will provide the basis for a careful study of this issue.

Study B.2.1. Patent uses and patent spillovers. An empirical analysis of the effectiveness of different means of knowledge spillovers from patents

R&D activities concentrate geographically. Like in production, economies of scale stimulate firms to locate R&D in one geographical area. In addition, innovative activities cluster geographically because they benefit from localised knowledge spillovers. Although there is an extensive literature on the existence of knowledge spillovers and the benefits of locating in the geographical cluster, one limitation of these studies is that they do not explain the sources of such spillovers. Most of them describe the spillovers as merely being "in the air". By using the information provided by the PatVal-EU survey on the sources of knowledge used to develop the patents, this contribution will investigate the mechanisms through which knowledge spillovers arise, and it will compare them to the use of patents to transfer knowledge. These data will be complemented by the information drawn from Regio, Who Owns Whom and Amadeus.

The aim of the study is twofold. First, it will describe the use of the different mechanisms for transferring knowledge across types of firms, sectors, regions, and countries. By controlling for many factors, it will estimate the probability to use these mechanisms conditional upon the characteristics of the organisations (e.g. small vs. large firms, universities, etc.), the characteristics of the regions (e.g. presence of scientific institutions, number of patents invented in the area, population density, etc.), sector and country specificities, and the characteristics of the inventors (education, carrier, etc.). The econometric analysis also considers the case in which the inventors use contemporaneously different mechanisms to transfer knowledge in order to produce a specific patent. The second goal of the paper is to compare the relative effectiveness of these coordination mechanisms to produce valuable innovations. To do so, the paper will use a non-parametric approach to highlight the average performance of the innovation process in different sub-classes characterised by different "coordination" mechanisms.

The third step of the research on spillovers will focus on the type of patents that are most used by other patents. The PatVal-EU survey identifies the motives for patenting. Patent citations to the PatVal-EU patents will be used as a measure of the spillovers that arise from the latter. As discussed in the tender for Lot 1, patent citations have been used by the literature as a measure of spillovers, and they will enable us to estimate the impact of different motives for patenting on how much the patent is cited. It will also suggest the extent to which the knowledge in that patent is used in the research leading to other patents.

We will devote particular attention to the "strategic" motives for patenting, viz. blocking rivals and prevention from imitation. Specifically, we will test whether the patents that have been applied for strategic reasons are cited less than others. This would suggest that: a) the availability of patents does induce their use by others (otherwise why should strategic patents be cited less than others?);

b) the social costs of strategic patenting are higher than the mere monopoly on the invention, as they also imply lower spillovers. We will break down our analysis by country, technological area and type of applicant whenever meaningful. In short, we will try to understand whether different motives for patenting lead to different degrees of spillovers. If so, policy can meaningfully manoeuvre the extent of the spillovers.

Study B.2.2. Spillovers through labour mobility from academia to business

This study will present the first representative set of information on patenting and spillovers in the Academia in Europe. With the help of the PatVal-EU data we will discuss the characteristics of European university patents in terms of ownership, technological class, country of inventor and mobility. Then we will focus on the analysis of the university researcher mobility. This is the first quantitative assessment of this phenomenon and it is the basis for a set of econometric models that try to explain how different factors affect the mobility of academics and their choices: to stay, to move to the private sector, to move to a different public research organisation (including another university). Mobility away from academia is a significant phenomenon at least for the sub-sample of university researchers that hold patents from the European Patent Office. The econometric models will provide evidence on the relationship between the value of the patents and the probability of the inventors to move to a company. We will also check for other factors like the characteristics of the inventors (i.e. are young researchers more likely to move than senior researchers?), or the characteristics of the knowledge base, the technological sector, the country, etc.

Study B.2.3. Spillovers at the level of the research unit

The purpose of this contribution that uses the PatVal-EU data will be to assess the existence of spillovers at the research unit level, defining as such the network of inventors that arises from the research done to create new patentable knowledge. We propose to identify a research unit in a novel way, by means of valuation techniques similar to the ones used in the theory of the firm, and therefore our measure can be interpreted as the present discounted value adjusted by the renewal cost of intellectual capital. We will assess empirically the importance of spillovers at the research unit level, by estimating the effect of spillovers on the present discounted value of the research unit adjusted by the replacement cost of intellectual capital. We will construct three different types of spillover pools. After correcting for sample selection and endogeneity, we expect the different spillover pools to come up positive and significant.

C) Policy Implications

Under this Heading we will provide a comprehensive discussion of the policy implications for enhancing the value of patents, their use, and more generally their social advantages vis-à-vis their social costs, following the empirical analyses of the previous headings. From the previous discussion of our empirical studies, we expect our policy implications to focus on issues such as: (1)

Policies for encouraging factors that have shown to be important determinants for producing high value patents; (2) Policies for enhancing the economic use of patents like licensing, markets for technology, or else; (3) Policies for reducing the social costs of patents; (4) Policies for enhancing R&D activities (5) Policies for enhancing employment effects from patents like the creation of new firms; (6) Policies for a better assessment of the strength of the patent protection by a more careful fine-tuning of social values and social costs of patents (e.g. by taking into account that different motives for patenting can give rise to different spillovers).

Datasets

The empirical analyses that we plan to conduct in Lot 2 require the combination of different datasets possessed by different members of the team. We will integrate the PatVal EU survey data with data from the patent documents or databases (e.g. applicant, technological class, citations, oppositions, renewals), and with data at the level of firms (e.g. size, financial data, R&D expenditures) and countries/regions (e.g. population, employment, GDP, intensity of technological activities). Firm and country/region data provide the necessary covariates for our empirical studies.

All our datasets have now been cleaned and organized, and they are ready to be used. We plan, however, to cover Denmark, Hungary and another New Member State (Estonia or Slovenia) with the PatVal-EU survey. Denmark will represent a small Scandinavian country, while the other survey in the other two countries will contribute to develop a better understanding of the patents' invention process and value in New Member States. By complementing the patent data with other firm and regional variables we will perform a comprehensive qualitative and quantitative evaluation of the impact of the patent system on the economy and society at different levels.

We already described in the Project the databases that we will use in our work. We list them again here:

- ZEW-EPO Patent Dataset.
- PatVal-EU Datasets, with the extension of the survey Hungary, Denmark and an additional New Member State.
- DELPHION – for additional patent variables (like number of claims, number of technological classes used as proxies for patent scope and protection).
- AMADEUS - on firm characteristics - (available at CERM/LEM)
- WOW (Who Owns Whom, 1997) - on firm and subsidiaries characteristics - (available at CERM/LEM)
- REGIO – on regional characteristics - (available at CERM/LEM)
- Country specific datasets on firm R&D Expenditures (like Mediocredito Centrale for Italy, DEP and CIS data for France; the Mannheim Innovation Panel for Germany).
- ISI, INIPI and OST classifications for the technological fields in which the patents are classified according to the International Patent Classification (IPC)

- The ZEW Search Engine to merge firm and patent data.

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ANNEX I. DATASET OF THE LITERATURE

Part of this project was devoted to the construction of a database that contains the publications included in survey of the literature. It is a database in Access format with a main table that lists all the references made to the literature. Each reference is also classified by research theme, country, technological class, theoretical and empirical content, etc. For each reference we also include a field with the abstract of the contribution (i.e. research question, methodology, results) and the relevance for the research themes of this project (i.e. the economic value and the impact of the patent, and the implications for the economy and society). This is a very flexible database that will enable a search for publications by theme, technological area, country, etc. To better understand the organisation of the literature dataset, the following list provides the details of the classification.

Information (i.e. fields in the Access table) on each publication of the reference list

- ID: Publication identification number
- Title of the publication
- Source:
  - Journal/Publisher
  - Volume / Pages
- Year of publication
- Author/s:
  - Author 1
  - Author 2
  - Author 3
  - Author 4
  - Author 5
- Type of publication:
  - Journal article
  - Book
  - Book chapter
  - Working paper
  - Report
- Abstract
- File availability (availability of the file in pdf format to be included in a CD-Rom):
  - Yes
  - No

- Citation ISI:

Number of citations received from the publications collected from the ISI Web of Science database (available since 1990).

Criteria used for classification of the publications

- Themes

  - A1 - Economic Value
  - A2 - Economic use
  - B1 - New firm creation and employment
  - B2 - Knowledge spillovers

- Second Theme

Some publications deal with more than one of the four themes of the project. In these cases we specify also the second theme of the publication.

- Key word – Sub-theme

Within each broad theme, we also classified the literature according to the main sub-theme classifies as a key word. For example, within the theme A1 we included sub-themes like Patent Citations, Skewness of the Patent Value Distribution, Litigations, etc.

- Theoretical/Empirical Codes:

  - (B) Both theory/empirical
  - (E) Empirical
  - (RB) Review Both theory/empirical
  - (RE) Review Empirical Literature
  - (RT) Review Theoretical Literature
  - (T) Theoretical

- Technological Areas

  - Multiple
  - Biotechnology
  - Pharmaceutical
  - Bio-pharma
  - Chemicals
  - Computing
  - Electronics
  - Electronic - Semiconductors
  - Communications
  - Electrical engineering
  - Mechanical engineering

- Instruments
- Production engineering
- Other

▪ Countries

- Germany
- France
- UK
- Italy
- Spain
- Netherlands
- Denmark
- Sweden
- Hungary
- US
- Japan
- Multiple
- Multiple (EU)

▪ Type of applicants' organization

- All
- Multiple
- All firms
- Large firm
- SMEs
- Public research institutions (incl. Universities)
- No profit research institutions
- Individual

When data had multiple items to be single out, the records are classified in aggregate terms. They are then analysed on a sectoral base, only if this is relevant to the analysis.

ANNEX II. COVERAGE OF THE LITERATURE SURVEY

This Annex shows the coverage of the literature we surveyed by theme, country, technological class, type of inventors' employer and type of contribution to the literature (i.e. theoretical/empirical). It was prepared by using the dataset of the literature that includes 164 key publications on the four themes. Each cell shows the frequencies of publications according to the selected criteria. 26 of these publications deal with two themes. For this reason the total number of observations of the Tables of the coverage of the literature by theme is 190. The rows or columns classified as "multiple" in the Tables below collects the contributions performed on aggregate data or on multiple entries (i.e. many countries or technologies).

Themes & Countries

Country	A1 - Economic Value	A2 - Economic use	B1 - New firm creation and employment	B2 - Knowledge spillovers	Other	Total
Multiple	18	12	2	6	-	38
Multiple (EU)	8	6	-	5	1	20
USA	25	22	12	15	-	74
Canada	1	-	-	-	-	1
Japan	3	3	-	2	-	8
India	-	1	-	-	-	1
France	1	-	-	-	-	1
Belgium	-	1	-	-	-	1
Germany	7	-	-	-	-	7
Italy	-	1	-	1	-	2
Sweden	1	-	1	-	-	2
United Kingdom	2	-	2	-	-	4
NA (theory or NA)	22	4	-	5	-	31
Total	88	50	17	34	1	190

Themes & Technologies

Industry	A1 - Economic Value	A2 - Economic use	B1 - New firm creation and employment	B2 - Knowledge spillovers	Other	Total
Multiple	51	38	14	27	1	131
Bio-pharma	1	2	-	-	-	3
Biotechnology	1	1	2	-	-	4
Pharmaceutical	4	-	-	1	-	5
Chemicals	-	1	-	-	-	1
Computing	1	-	-	-	-	1
Communications	1	-	-	-	-	1
Electronic - Semiconductors	3	3	-	1	-	7
Instruments	1	-	-	-	-	1
Mechanical engineering	2	1	-	-	-	3
Other	1	-	1	-	-	2
NA (theory or NA)	22	4	-	5	-	31
Total	88	50	17	34	1	190

Themes & Inventors' organizations

Inventor type	A1 - Economic Value	A2 - Economic use	B1 - New firm creation and employment	B2 - Knowledge spillovers	Other	Total
Multiple	7	7	1	4	-	19
All	24	7	-	13	-	44
All firms	29	23	2	5	-	59
Large firm	4	2	1	3	-	10
SMEs	1	1	2	1	1	6
Public research institutions (incl. Universities)	-	3	9	2	-	14
Individual	-	2	2	1	-	5
NA (theory or NA)	23	5	-	5	-	33
Total	88	50	17	34	1	190

Theme & Type of contribution

Theory/Empirical	A1 - Economic Value	A2 - Economic use	B1 - New firm creation and employment	B2 - Knowledge spillovers	Other	Total
NA (theory or NA)	-	1	-	-	1	2
Both theory/empirical	7	9	1	-	-	17
Empirical	49	29	15	24	-	117
Review Both theory/empirical	8	4	-	3	-	15
Review Empirical Literature	9	2	1	6	-	18
Review Theoretical Literature	1	1	-	-	-	2
Theoretical	14	4	-	1	-	19
Total	88	50	17	34	1	190

Countries & Technologies

Countries & Technologies	Multiple	Multiple (EU)	USA	Canada	Japan	India	France	Belgium	Germany	Italy	Sweden	United Kingdom	Other	Total
Multiple	23	17	49	1	8	1	1	1	6	6	1	3	-	117
Bio-pharma	1	1	1	-	-	-	-	-	-	-	-	-	-	3
Biotechnology	2	-	2	-	-	-	-	-	-	-	-	-	-	4
Pharmaceutical	1	-	2	-	-	-	-	-	-	-	1	1	-	5
Chemicals	1	-	-	-	-	-	-	-	-	-	-	-	-	1
Computing	-	-	1	-	-	-	-	-	-	-	-	-	-	1
Communications	1	-	-	-	-	-	-	-	-	-	-	-	-	1
Electronic - Semiconductors	-	-	5	-	-	-	-	-	1	1	-	-	-	7
Instruments	-	-	1	-	-	-	-	-	-	-	-	-	-	1
Mechanical engineering	1	1	-	-	-	-	-	-	-	-	-	-	-	2
Other	-	-	1	-	1	-	-	-	-	-	-	-	-	2
NA (theory or NA)	-	-	-	-	-	-	-	-	-	-	-	-	25	25
Total	30	19	62	1	9	1	1	1	7	7	2	4	25	169

Countries & Inventors' organizations

Countries & Inventors' organizations	Multiple	Multiple (EU)	USA	Canada	Japan	India	France	Belgium	Germany	Italy	Sweden	United Kingdom	Other	Total
Multiple	7	2	3	-	3	-	-	-	-	-	-	-	-	15
All	11	8	11	-	1	-	1	-	4	1	-	-	-	37
All firms	10	3	28	1	4	1	-	1	2	-	1	2	-	53
Large firm	2	2	3	-	-	-	-	-	1	-	-	1	-	9
SMEs	-	2	3	-	-	-	-	-	-	-	1	-	-	6
Public research institutions (incl. Universities)	1	-	11	-	-	-	-	-	-	-	-	1	-	13
Individual	-	-	3	-	-	-	-	-	-	1	-	-	-	4
NA (theory or NA)	-	2	-	-	-	-	-	-	-	-	-	-	25	27
Total	31	19	62	1	8	1	1	1	7	2	2	4	25	164

Inventors' organizations & Technologies

Inventor type	Multiple	Bio-pharma	Biotechnology	Pharmaceutical	Chemicals	Computing	Communications	Electronic - Semiconductors	Instruments	Mechanical engineering	Other	NA (theory or NA)	Total
Multiple	12	2	1	-	-	-	-	-	-	-	-	-	15
All	34	1	1	-	-	-	-	-	1	-	-	-	37
All firms	39	-	-	4	1	1	1	4	-	2	1	-	53
Large firm	7	-	-	1	-	-	-	1	-	-	-	-	9
SMEs	5	-	1	-	-	-	-	-	-	-	-	-	6
Public research institutions (incl. Universities)	12	-	-	-	-	-	-	-	-	-	1	-	13
Individual	2	-	1	-	-	-	-	1	-	-	-	-	4
NA (theory or NA)	2	-	-	-	-	-	-	-	-	-	-	25	27
Total	113	3	4	5	1	1	1	6	1	2	2	25	164

Annex III. Additional Descriptive Statistics from the PatVal-EU Dataset

The Tables in this Annex complement the Report by providing additional descriptive statistics on the PatVal-EU data. The first three Tables in this Annex show some basic data on the composition of the PatVal-EU dataset. Specifically, they list the technological classes in which the patents in the sample are classified both at the micro and macro level and, by conditioning on the (micro and macro) technological classes, they provide the share of patents applied by different employers' organisations.

The rest of Annex III collects additional Tables on the four themes presented in the Report, and in so doing it reproduces the structure of the Report as follows:

AIII.1. The value and social costs of patents

AIII.2. The economic use of patents:
- The use of patents
- The importance of different motives for patenting

AIII.3. The creation of new businesses from the patented inventions

AIII.4. Collaborations, spillovers and the sources of knowledge in the invention process:
- Collaboration among inventors in the innovations process
- Formal and informal collaborations in research
- The role of geographical proximity for collaboration
- The sources of knowledge.

Table A.1 List of Macro and Micro technological classes

Macro Technological Class	Micro Technological Class
Electrical engineering	Electrical devices, electrical engineering, electrical energy
Electrical engineering	Audio-visual technology
Electrical engineering	Telecommunications
Electrical engineering	Information technology
Electrical engineering	Semiconductors
Instruments	Optics
Instruments	Analysis, measurement, control technology
Instruments	Medical technology
Instruments	Nuclear engineering
Chemistry, Pharmaceuticals	Organic fine chemistry
Chemistry, Pharmaceuticals	Macromolecular chemistry, polymers
Chemistry, Pharmaceuticals	Pharmaceuticals, cosmetics
Chemistry, Pharmaceuticals	Biotechnology
Chemistry, Pharmaceuticals	Agriculture, food chemistry
Chemistry, Pharmaceuticals	Chemical and petrol industry, basic materials chemistry
Process engineering	Materials, metallurgy
Process engineering	Chemical engineering
Process engineering	Surface technology, coating
Process engineering	Materials processing, textiles, paper
Process engineering	Environmental technology
Process engineering	Handling, printing
Process engineering	Agricultural and food processing, machinery and apparatus
Mechanical engineering	Thermal processes and apparatus
Mechanical engineering	Machine tools
Mechanical engineering	Engines, pumps, turbines
Mechanical engineering	Mechanical Elements
Mechanical engineering	Transport
Mechanical engineering	Space technology weapons
Mechanical engineering	Consumer goods and equipment
Mechanical engineering	Civil engineering, building, mining

Table A. 2 Composition of the sample by macro technological class and type of inventors' employer

	Employer Type								Total
	Large companies	Medium sized companies	Small companies	Private Research Institutions	Public Research Institutions	Universities	Other Governm. Institutions	Others	
Electrical Engineering	79.89%	5.49%	9.13%	0.43%	1.85%	2.85%	0.07%	0.29%	100.00%
Instruments	60.42%	7.85%	16.65%	3.25%	3.77%	7.02%	0.10%	0.94%	100.00%
Chemical & Pharmaceutical tech.	81.16%	4.88%	4.94%	0.61%	2.56%	5.67%	0.12%	0.06%	100.00%
Process Engineering	64.37%	12.29%	17.18%	0.69%	2.24%	2.42%	0.23%	0.59%	100.00%
Mechanical Engineering	67.86%	10.48%	17.80%	0.19%	1.07%	1.18%	0.19%	1.22%	100.00%
Total	70.58%	8.81%	13.75%	0.76%	2.05%	3.22%	0.16%	0.67%	100.00%

Number of observations = 8,809

Table A. 3 Composition of the sample by micro technological class and type of inventors' employer

ISI Technological Classes	Employer Type								
	Large companies	Medium sized companies	Small companies	Private Research Institutions	Public Research Institutions	Universities	Other Governm. Institutions	Others	Total
Electrical Devices, Electrical Eng. & Electrical Energy	78.41	7.65	9.75	0.15	2.10	1.80	0.00	0.15	100.00
Audio-visual Technology	77.06	4.12	12.94	0.00	1.76	4.12	0.00	0.00	100.00
Telecommunications	87.90	2.85	4.98	0.71	0.36	2.14	0.00	1.07	100.00
Information Technology	73.37	4.52	11.56	1.51	2.51	6.03	0.50	0.00	100.00
Semiconductors	85.88	2.35	4.71	0.00	3.53	3.53	0.00	0.00	100.00
Optics	76.22	3.66	9.15	0.00	4.27	6.10	0.00	0.61	100.00
Analysis, Measurement, & Control Technology	64.07	8.94	14.07	0.38	4.18	7.79	0.19	0.38	100.00
Medical Technology	40.00	8.44	28.89	12.89	1.78	5.33	0.00	2.67	100.00
Organic Fine Chemistry	82.90	4.65	3.35	0.00	2.60	6.51	0.00	0.00	100.00
Macromolecular Chemistry & Polymers	87.77	3.93	4.15	0.00	0.87	3.06	0.22	0.00	100.00
Pharmaceuticals & Cosmetics	72.94	6.47	9.41	2.35	2.94	5.88	0.00	0.00	100.00
Biotechnology	47.06	1.47	7.35	4.41	16.18	22.06	1.47	0.00	100.00
Materials & Metallurgy	75.49	5.56	9.15	0.98	4.90	2.61	0.00	1.31	100.00
Agriculture, & Food Chemistry	62.73	13.64	10.91	0.91	4.55	7.27	0.00	0.00	100.00
Chemical & Petrol Industry, Basic Materials Chemistry	87.16	3.38	3.72	0.68	1.01	3.72	0.00	0.34	100.00
Chemical Engineering	56.12	11.15	21.58	0.72	3.96	5.40	0.36	0.72	100.00
Surface Technology & Coating	67.16	12.69	14.18	0.00	1.49	4.48	0.00	0.00	100.00
Materials Processing, Textiles & Paper	66.46	14.35	15.40	0.63	1.48	1.48	0.21	0.00	100.00
Thermal Processes & Apparatus	65.05	6.45	24.19	0.54	3.23	0.54	0.00	0.00	100.00
Environmental Technology	61.27	7.75	17.61	0.70	6.34	5.63	0.00	0.70	100.00
Machine Tools	66.67	11.86	17.95	0.00	1.92	0.64	0.32	0.64	100.00
Engines, Pumps & Turbines	82.21	5.53	7.91	0.00	1.58	0.79	0.00	1.98	100.00
Mechanical Elements	74.28	10.50	11.02	0.00	1.05	1.84	0.00	1.31	100.00
Handling & Printing	66.77	13.68	17.14	0.60	0.30	0.90	0.00	0.60	100.00
Agricultural & Food Processing, Machinery & Apparatus	45.26	17.89	30.00	1.05	1.58	1.58	1.58	1.05	100.00
Transport	77.36	7.49	11.89	0.00	0.65	1.30	0.33	0.98	100.00
Nuclear Engineering	62.50	7.50	12.50	0.00	7.50	10.00	0.00	0.00	100.00
Space Technology Weapons	75.44	10.53	14.04	0.00	0.00	0.00	0.00	0.00	100.00
Consumer Goods & Equipment	59.24	12.47	23.16	0.67	0.67	1.34	0.22	2.23	100.00
Civil Eng., Building & Mining	47.44	17.25	32.08	0.27	0.27	1.35	0.27	1.08	100.00
Total	70.58	8.81	13.75	0.76	2.05	3.22	0.16	0.67	100.00

Number of observations = 8,809

A III.1 The value and social costs of patents

This section collects five Tables on the economic value and social costs of patents. Specifically, Table A.4 shows the average economic value of European patents invented by applicants located in only one country as compared to applicants located in more than one country. In so doing it looks at the relationship between the probability of developing important innovations and the setting up of international links among institutions in developing or simply applying for a patent. Table A.5 looks at the average economic value of European patents conditioned on the country of the applicant. When there is only one applicant, or when there are multiple applicants from the same country we differentiate among the following possibilities: (1) "domestic" European countries, meaning that the country of the applicant/s is one of the 6 European countries involved in the survey, and it is the same as the country of the inventor that we interviewed; (2) other European countries ("other EU"), meaning that the country of the applicant is a European country but it differs from the country of the interviewed inventor; (3) USA, i.e. American applicants; (4) non EU/US, i.e. applicants located in countries other than European and American countries. If there are multiple applicants located in different countries we classified these patents as applied by foreign countries: (5) Co-assigned Foreign.

Table A.6 shows the average value of patents invented by the NUTS2 regions in which they were invented. It lists only the regions for which the average patent value is lower than the EU6 average. Table A.7 reports the number of man-months needed to develop the innovations by number of countries in which the applicants are located, while Table A.8 indicates the number of man-months by the country of the applicant.

The value of patents

Table A. 4 The value of European patents. Number of countries in which the applicants are located

	1 country	More than 1 country	Total
<30k	7.85%	8.76%	7.88%
30k-100k	17.59%	11.55%	17.39%
100k-300k	20.64%	21.12%	20.66%
300k-1m	21.83%	21.12%	21.80%
1m-3m	15.45%	15.54%	15.46%
3m-10m	9.52%	11.55%	9.59%
10m-30m	3.69%	3.59%	3.69%
30m-100m	1.89%	5.18%	2.00%
100m-300m	0.77%	0.40%	0.76%
>300m	0.76%	1.20%	0.77%
Total	100.00%	100.00%	100.00%
Average patent value	6,262 (30,194)	9,251 (36,294)	6,359 (30,413)
Average number of forward citations	0.92 (1.81)	0.74 (1.72)	0.91 (1.80)
Share of opposed patents	8.64%	7.43%	8.60%
Number of observations	8717	296	9013

Note: standard deviations in parenthesis.
The category "1 country" includes patents with only 1 applicant and patents with more than 1 applicant located in the same country. The number of observations shown in this Table refers to the number of forward citations and opposed patents. For the average patent value the number of observation is 7,751.

Table A. 5 The value of European patents. Distribution by applicants' country

	Domestic applicant	European applicant	USA applicant	Non-EU & non-USA applicant	Non-domestic co-applicant	Total
<30k	8.13%	5.35%	4.56%	5.88%	8.90%	7.88%
30k-100k	17.84%	16.31%	12.98%	17.65%	11.44%	17.39%
100k-300k	20.77%	20.32%	16.49%	23.53%	22.46%	20.65%
300k-1m	21.65%	21.93%	25.61%	20.59%	21.61%	21.80%
1m-3m	15.20%	17.91%	17.19%	23.53%	15.68%	15.45%
3m-10m	9.50%	9.36%	11.58%	2.94%	11.02%	9.58%
10m-30m	3.56%	4.81%	5.96%	2.94%	3.39%	3.70%
30m-100m	1.85%	2.41%	3.16%	2.94%	4.24%	2.00%
100m-300m	0.75%	1.07%	1.40%	0.00%	0.00%	0.76%
>300m	0.76%	0.53%	1.05%	0.00%	1.27%	0.77%
Total	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
Average patent value	6,173.36 (30,109.91)	6,556.86 (28,249.27)	9,422.09 (36,486.80)	3,079.41 (11,269.43)	8,211.80 (35,690.17)	6,359.79 (30,410.79)
Average number of forward citations	0.92 (1.81)	0.92 (1.92)	0.76 (1.49)	0.97 (1.86)	0.77 (1.76)	0.91 (1.80)
Share of opposed patents	8.67%	7.60%	8.66%	10.26%	7.89%	8.60%
Number of observations	7926	434	335	39	279	9013

Note: standard deviations in parenthesis. The number of observations shown in this Table refers to the number of forward citations and opposed patents. For the average patent value the number of observation is 7,752.

Table A. 6 The value of European patents across European regions (NUTS2)

Country	NUTS 2	Average value (st dev)	Average Forward Cits (St dev)	% Opposed patents	Number of obs.
Total		6358.35 (30407.00)	0.911683 (1.80)	8.60%	9013
UK	Hampshire and Isle of Wight	6350.53 (23487.82)	0.23 (0.54)	1.82%	55
IT	Lazio	6286.94 (26834.14)	1.20 (2.01)	5.71%	35
UK	Merseyside	6264.85 (15748.23)	0.18(0.51)	18.42%	38
UK	Herefordshire, Worcestershire and Warks	5818.41 (22618.10)	0.22 (0.51)	10.20%	49
IT	Emilia-Romagna	5630.35 (28934.07)	0.85 (1.35)	10.47%	172
FR	Midi-pyrénées	5481.49 (23607.04)	0.32 (0.89)	7.04%	71
NL	Noord-Holland	5407.99 (20507.50)	0.12 (0.38)	3.42%	117
NL	Gelderland	5153.56 (28198.63)	0.25 (0.82)	9.30%	129
UK	West midlands	5153.00 (19392.08)	0.34 (1.21)	3.49%	86
NL	Overijssel	5091.21 (13989.00)	0.35 (1.17)	4.84%	62
FR	Pays de la Loire	4919.57 (25370.17)	0.45 (0.90)	8.33%	48
UK	Greater Manchester	4735.07 (13009.17)	0.23 (0.58)	3.85%	78
FR	Rhône-alpes	4487.84 (19528.41)	0.63 (1.10)	14.03%	278
NL	Zuid-Holland	4395.74 (15877.93)	0.17 (0.58)	7.65%	183
IT	Veneto	4354.10 (29739.92)	0.85 (1.07)	7.89%	114
DE	Darmstadt	4297.22 (21753.44)	2.09 (2.72)	11.26%	364
FR	Île de France	4249.92(18704.78)	0.72 (1.37)	11.47%	436
NL	Utrecht	4224.59 (11915.35)	0.22 (0.48)	4.62%	65
UK	East Anglia	4155.36 (10445.97)	0.06 (0.34)	1.82%	110
UK	Essex	3855.97 (5813.057)	0.27 (0.76)	4.55%	44
DE	Köln	3826.21 (22511.52)	1.90 (2.75)	9.22%	217
UK	Gloucestershire, Wiltshire and North Somerset	3615.90 (10487.54)	0.19 (0.50)	4.49%	89
DE	Koblenz	3556.94 (11630.42)	0.84 (1.22)	3.13%	32
DE	Hamburg	3341.56 (13086.16)	1.54 (1.67)	13.46%	52
DE	Oberbayern	3161.99 (14345.29)	1.67 (2.28)	5.90%	339
DE	Arnsberg	3124.29 (10028.10)	1.56 (1.74)	9.90%	101
DE	Düsseldorf	3100.04 (14316.56)	1.58 (2.66)	11.90%	311
FR	Nord - Pas-de-Calais	3024.19 (10264.21)	0.48 (1.05)	18.00%	50
FR	Alsace	2783.37 (9916.52)	0.81 (1.31)	20.63%	63
FR	Picardie	2780.31 (11463.05)	0.83 (1.17)	12.50%	40
DE	Berlin	2610.00 (9153.55)	0.80 (1.39)	6.15%	65
DE	Tübingen	2523.26 (8850.67)	1.66 (2.26)	11.45%	131
DE	Münster	2506.64 (9142.814)	1.28 (1.43)	19.67%	61
FR	Bourgogne	2384.57 (10956.28)	0.65 (1.20)	11.76%	51
DE	Schwaben	2361.58 (10236.55)	1.79 (2.68)	10.71%	84
DE	Detmold	2328.88 (10261.24)	1.75 (2.23)	13.64%	44
DE	Stuttgart	1919.71 (9479.97)	1.40 (1.94)	7.80%	346
DE	Mittelfranken	1377.34 (3076.14)	1.16 (1.91)	12.50%	136
FR	Centre	1148.94 (2600.32)	0.49 (1.00)	9.23%	65
FR	Languedoc-Roussillon	1017.26 (2855.59)	0.67 (1.12)	7.14%	42
DE	Oberpfalz	975.53 (1964.04)	1.16 (1.98)	10.20%	49
DE	Unterfranken	834.71 (1502.37)	1.76 (2.27)	18.97%	58

Note: standard deviations in parentheses. The number of observations shown in this Table refers to the number of forward citations and opposed patents. For the average patent value the number of observation is 7,754.
This Table includes the European regions in which the average value of patents is below the EU6 average and the number of observation in each region is ≥30.

The cost of patents

Table A. 7 The man-months required by the patents' invention process. Number of countries in which the applicants are located

	1 country	More than 1 country	Total
<1	12.83%	6.27%	12.62%
1-3	20.54%	19.19%	20.50%
4-6	19.17%	17.71%	19.13%
7-12	18.21%	18.45%	18.22%
13-24	15.34%	22.14%	15.56%
25-48	8.56%	9.23%	8.58%
49-72	2.13%	1.85%	2.12%
>72	3.21%	5.17%	3.28%
Total	100.00%	100.00%	100.00%

Table A. 8 The man-months required by the patents' invention process. Distribution by applicants' country

	Domestic applicant	European applicant	USA applicant	Non-EU & non-USA applicant	Non-domestic co-applicant	Total
<1	12.71%	13.83%	13.95%	11.43%	6.67%	12.62%
1-3	20.33%	21.98%	23.26%	22.86%	19.61%	20.51%
4-6	19.51%	16.05%	16.28%	8.57%	17.65%	19.12%
7-12	18.07%	20.00%	18.27%	22.86%	18.82%	18.22%
13-24	15.32%	15.56%	14.95%	22.86%	22.35%	15.56%
25-48	8.72%	6.91%	7.97%	5.71%	8.24%	8.58%
49-72	2.12%	1.98%	2.66%	2.86%	1.57%	2.12%
>72	3.22%	3.70%	2.66%	2.86%	5.10%	3.28%
Total	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%

AIII.2 The economic use of patents

Tables A.9 and A.10 in this section look at the economic use of patents (i.e. Internal use; Licensing; Cross-licensing; Licensing & Use; Blocking competitors; Sleeping patents) as defined in Section 3.3. They show their distribution conditioned on the country of the applicant. Specifically, Table A.9 looks at the use of patents when the applicants are located in only one country as compared to patents whose applicants are located in more than one country. Table A.10 describes the use of European patents by the country of the applicants.

The use of patents

Table A. 9 The economic use of European patents. Number of countries in which the applicants are located.

	Internal use	Licensing	Cross-licensing	Licensing & Use	Blocking Competitors	Sleeping Patents	Total
1 country	50.80%	6.53%	2.97%	4.03%	18.36%	17.32%	100.00%
More than 1 country	42.21%	2.28%	4.56%	2.28%	28.14%	20.53%	100.00%
Total	50.51%	6.38%	3.02%	3.97%	18.69%	17.43%	100.00%

Number of observations = 7710

Table A. 10 The economic use of European patents. Distribution by applicants' country

	Internal use	Licensing	Cross-licensing	Licensing & Use	Blocking Competitors	Sleeping Patents	Total
Domestic applicant	6.62%	4.07%	2.94%	50.72%	17.83%	17.83%	100.00%
European applicant	5.50%	4.75%	2.50%	49.50%	22.75%	15.00%	100.00%
USA applicant	5.38%	2.53%	3.48%	53.80%	24.68%	10.13%	100.00%
Non-EU & non-USA applicant	8.33%	2.78%	8.33%	55.56%	19.44%	5.56%	100.00%
Non-domestic co-applicant	2.43%	2.02%	4.86%	41.30%	27.53%	21.86%	100.00%
Total	6.38%	3.97%	3.02%	50.50%	18.69%	17.44%	100.00%

Number of observations = 7711

The importance of different motives for patenting

Tables A.11-A.14 show the importance of six different motives for patenting for the organizations in which the inventors were employed at the time of the invention. Compared to the "actual use of patents" made by the organisations, this part of the survey looked at the motives that led the inventors and their organisations to ask for patent protection. We distinguished among six motives for patenting: commercial exploitation, licensing, cross-licensing, prevention from imitation, blocking patents, and reputation. By using a score from 1 to 5, Table A.11 describes the importance of the six motives for patenting across the countries involved in the survey. Table A.12 shows their importance across the micro technological classes used in this Report. Table A.13 looks at the importance of different motives for patenting when the applicants of the patent are located in one country as compared to applicants located in more than one country. Table A.14 looks at European vs. non-European origins of the applicants, and links this information to the importance of the different motives for patenting.

Table A. 11 The importance of different motives for patenting by country

	DE	ES	FR	IT	NL	UK	Total
Commercial exploitation	3.64 (1.56)	4.09 (1.39)	3.89 (1.47)	3.58 (1.75)	3.70 (1.65)	4.23 (1.29)	3.79 (1.56)
Licensing	2.15 (1.33)	2.68 (1.72)	1.65 (1.41)	1.52 (1.51)	1.93 (1.77)	2.45 (1.66)	2.06 (1.54)
Cross-licensing	1.85 (1.22)	1.46 (1.31)	2.09 (1.62)	1.37 (1.41)	1.66 (1.79)	1.99 (1.47)	1.78 (1.44)
Prevention from imitation	4.01 (1.40)	3.78 (1.60)	3.61 (1.64)	3.63 (1.77)	3.28 (1.80)	3.71 (1.56)	3.76 (1.60)
Blocking patents	2.45 (1.50)	3.47 (1.63)	3.32 (1.73)	3.35 (1.86)	3.39 (1.75)	3.45 (1.62)	3.00 (1.70)
Reputation	2.24 (1.34)	2.90 (1.65)	2.20 (1.55)	2.17 (1.75)	1.79 (1.67)	2.61 (1.60)	2.26 (1.56)

Note: standard deviations in parenthesis.

Table A. 12 The importance of different motives for patenting by micro technological class

ISI Technological Classes	Commercial exploitation	Licensing	Cross-licensing	Prevention from imitation	Blocking patents	Reputation
Electrical Devices, Electrical Eng. & Electrical Energy	3.75 (1.52)	2.03 (1.50)	2.15 (1.57)	3.94 (1.44)	3.06 (1.68)	2.28 (1.54)
Audio-visual Technology	3.53 (1.71)	2.50 (1.68)	2.87 (1.66)	3.38 (1.70)	3.14 (1.66)	2.33 (1.63)
Telecommunications	3.30 (1.59)	2.40 (1.55)	3.02 (1.67)	3.29 (1.63)	3.02 (1.55)	2.61 (1.64)
Information Technology	3.50 (1.50)	2.58 (1.47)	3.05 (1.48)	3.47 (1.54)	3.01 (1.58)	2.77 (1.36)
Semiconductors	3.33 (1.53)	2.29 (1.59)	3.05 (1.61)	3.61 (1.41)	2.88 (1.51)	2.91 (1.61)
Optics	3.67 (1.57)	2.33 (1.60)	2.63 (1.70)	3.79 (1.35)	3.08 (1.56)	2.54 (1.66)
Analysis, Measurement, & Control Technology	3.64 (1.63)	2.16 (1.58)	1.89 (1.50)	3.66 (1.58)	2.74 (1.72)	2.41 (1.53)
Medical Technology	3.91 (1.55)	2.16 (1.52)	1.74 (1.39)	3.65 (1.69)	2.89 (1.65)	2.32 (1.60)
Organic Fine Chemistry	3.95 (1.44)	2.23 (1.51)	1.75 (1.32)	3.54 (1.69)	3.05 (1.66)	2.25 (1.47)
Macromolecular Chemistry & Polymers	3.87 (1.48)	2.01 (1.42)	1.66 (1.26)	3.88 (1.45)	3.06 (1.63)	2.31 (1.48)
Pharmaceuticals & Cosmetics	3.86 (1.47)	2.43 (1.66)	1.84 (1.54)	3.61 (1.67)	3.10 (1.67)	2.36 (1.55)
Biotechnology	3.68 (1.70)	2.51 (1.88)	1.75 (1.63)	2.95 (1.78)	2.41 (1.90)	2.29 (1.75)
Materials & Metallurgy	3.75 (1.47)	2.20 (1.47)	1.67 (1.22)	3.61 (1.65)	2.86 (1.63)	2.50 (1.55)
Agriculture, & Food Chemistry	3.88 (1.57)	1.81 (1.69)	1.05 (1.15)	3.61 (1.75)	3.41 (1.73)	1.93 (1.63)
Chemical & Petrol Industry, Basic Materials Chemistry	4.08 (1.35)	1.97 (1.46)	1.67 (1.32)	3.69 (1.64)	3.26 (1.68)	2.08 (1.52)
Chemical Engineering	3.92 (1.45)	2.35 (1.65)	1.57 (1.24)	3.57 (1.69)	2.68 (1.69)	2.16 (1.49)
Surface Technology & Coating	3.81 (1.44)	2.20 (1.62)	1.70 (1.31)	3.74 (1.56)	3.01 (1.68)	2.51 (1.58)
Materials Processing, Textiles & Paper	3.75 (1.61)	2.02 (1.55)	1.56 (1.28)	3.80 (1.57)	3.17 (1.69)	2.11 (1.54)
Thermal Processes & Apparatus	3.47 (1.73)	2.02 (1.57)	1.43 (1.24)	3.67 (1.66)	2.89 (1.73)	2.09 (1.51)
Environmental Technology	3.63 (1.63)	2.29 (1.62)	1.58 (1.26)	3.37 (1.76)	2.47 (1.70)	2.58 (1.63)
Machine Tools	3.83 (1.60)	1.73 (1.43)	1.36 (1.15)	3.82 (1.62)	2.94 (1.76)	2.14 (1.51)
Engines, Pumps & Turbines	3.64 (1.62)	2.17 (1.54)	1.76 (1.32)	3.82 (1.52)	3.05 (1.70)	2.35 (1.45)
Mechanical Elements	3.77 (1.52)	1.97 (1.41)	1.50 (1.10)	3.90 (1.52)	2.87 (1.69)	2.29 (1.52)
Handling & Printing	3.89 (1.64)	1.66 (1.40)	1.51 (1.31)	3.99 (1.58)	3.19 (1.76)	2.05 (1.59)
Agricultural & Food Processing, Machinery & Apparatus	3.96 (1.53)	1.81 (1.64)	1.44 (1.42)	4.08 (1.55)	3.18 (1.81)	1.75 (1.63)
Transport	3.79 (1.58)	2.09 (1.51)	1.80 (1.43)	3.95 (1.49)	2.92 (1.70)	2.26 (1.53)
Nuclear Engineering	3.41 (1.61)	2.27 (1.48)	1.86 (1.49)	3.22 (2.00)	2.38 (1.74)	2.68 (1.68)
Space Technology Weapons	4.09 (1.31)	1.91 (1.31)	1.77 (1.38)	4.07 (1.35)	3.07 (1.70)	2.35 (1.31)
Consumer Goods & Equipment	3.73 (1.72)	1.67 (1.54)	1.40 (1.30)	3.88 (1.63)	3.20 (1.80)	1.97 (1.56)
Civil Eng., Building & Mining	4.14 (1.45)	1.98 (1.66)	1.33 (1.22)	3.84 (1.64)	2.95 (1.82)	2.07 (1.61)
Total	3.78 (1.56)	2.06 (1.54)	1.78 (1.44)	3.76 (1.60)	3.00 (1.70)	2.25 (1.56)

Note: standard deviations in parenthesis.

Table A. 13 The importance of different motives for patenting. Number of countries in which the applicants are located

	1 country	More than 1 country	Total
Commercial exploitation	3.78 (1.57)	3.85 (1.51)	3.78 (1.56)
Licensing	2.06 (1.54)	2.04 (1.58)	2.06 (1.54)
Cross-licensing	1.77 (1.43)	2.06 (1.68)	1.78 (1.44)
Prevention from imitation	3.76 (1.59)	3.51 (1.68)	3.75 (1.60)
Blocking patents	3.00 (1.71)	3.18 (1.66)	3.00 (1.70)
Reputation	2.26 (1.56)	2.15 (1.58)	2.25 (1.56)

Note: standard deviations in parenthesis.

Table A. 14 The importance of different motives for patenting by nationality of the applicants

	Domestic applicant	European applicant	USA applicant	Non-EU & non-USA applicant	Non-domestic co-applicant	Total
Commercial exploitation	3.77 (1.57)	3.77 (1.62)	4.01 (1.50)	4.31 (1.42)	3.85 (1.49)	3.78 (1.56)
Licensing	2.07 (1.54)	2.01 (1.59)	1.90 (1.57)	2.28 (1.62)	2.03 (1.58)	2.06 (1.54)
Cross-licensing	1.76 (1.41)	1.77 (1.48)	1.90 (1.60)	2.56 (1.79)	2.09 (1.68)	1.78 (1.44)
Prevention from imitation	3.76 (1.59)	3.71 (1.64)	3.93 (1.49)	3.23 (1.93)	3.46 (1.69)	3.76 (1.60)
Blocking patents	2.96 (1.70)	3.13 (1.70)	3.56 (1.65)	3.28 (1.62)	3.21 (1.65)	3.00 (1.70)
Reputation	2.25 (1.55)	2.18 (1.59)	2.42 (1.62)	2.87 (1.76)	2.18 (1.58)	2.25 (1.56)

Note: standard deviations in parenthesis.

A III.3 The creation of new businesses from the patented inventions

This part of Annex III adds some statistics on the creation of new businesses from the patented inventions. Table A.15 shows the share of new firms created from the patented inventions by NUTS2 European region for which this share is below the EU6 average. Figure A.1 shows the share of new firms created from the patented inventions, and distinguishes between individual inventors who applied for the patent, and applicant organisations (one or more than one). Figure A.2 looks at the share of patents used to create a new firm when the applicants of the patent are located in one country as compared to applicants located in more than one country. Figures A.3 and A.4 show the share of patents used to create a new venture by country and nationality of the applicants.

Table A. 15 Share of new firms from patented inventions by European regions (NUTS2)

Country	NUTS2	% New firms	N
Total		5.13%	7394
UK	Outer London	4.88%	41
NL	Overijssel	4.84%	62
NL	Utrecht	4.62%	65
IT	Piemonte	4.62%	195
DE	Tübingen	4.50%	111
UK	Herefordshire, Worcestershire and Warks	4.17%	48
IT	Friuli-Venezia Giulia	4.11%	73
DE	Mittelfranken	4.07%	123
UK	Cheshire	4.00%	50
FR	Île de France	3.96%	101
IT	Toscana	3.64%	55
NL	Limburg	3.51%	114
NL	Zuid-Holland	3.30%	182
DE	Oberbayern	2.88%	312
IT	Lazio	2.86%	35
DE	Schwaben	2.74%	73
DE	Stuttgart	2.71%	295
NL	Noord-Brabant	2.69%	334
DE	Detmold	2.56%	39
DE	Köln	2.56%	195
DE	Hannover	2.50%	80
DE	Oberpfalz	2.22%	45
DE	Rheinhessen-Pfalz	2.22%	180
DE	Unterfranken	2.04%	49
UK	Kent	2.04%	49
DE	Berlin	1.96%	51
DE	Düsseldorf	1.83%	273
DE	Münster	1.82%	55
DE	Darmstadt	1.49%	335
DE	Freiburg	1.22%	82
FR	Rhône-Alpes	1.19%	84
DE	Arnsberg	1.10%	91
FR	Alsace	0.00%	30
DE	Hamburg	0.00%	47

Note: This Table includes the European regions in which the share of new firms from patented inventions is below the EU6 average and the number of observation in each region is ≥30.

Figure A. 1 Share of new firms created by type of applicant: individual inventors vs. organisations

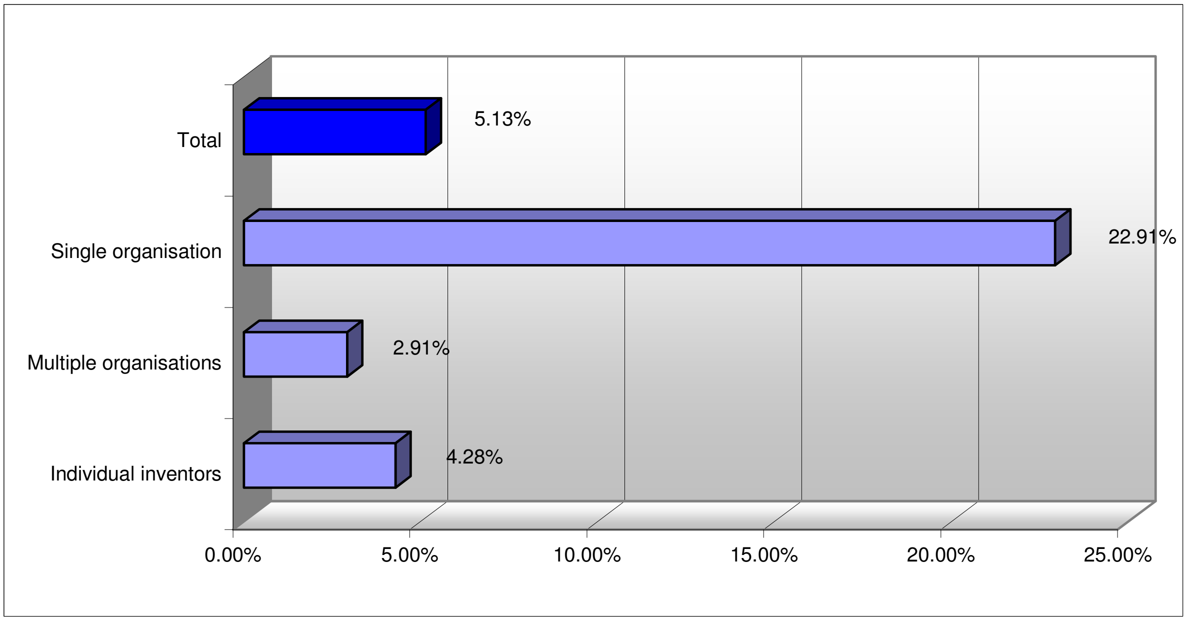


Figure A. 2 Share of new firm formation. Number of countries in which the applicants are located

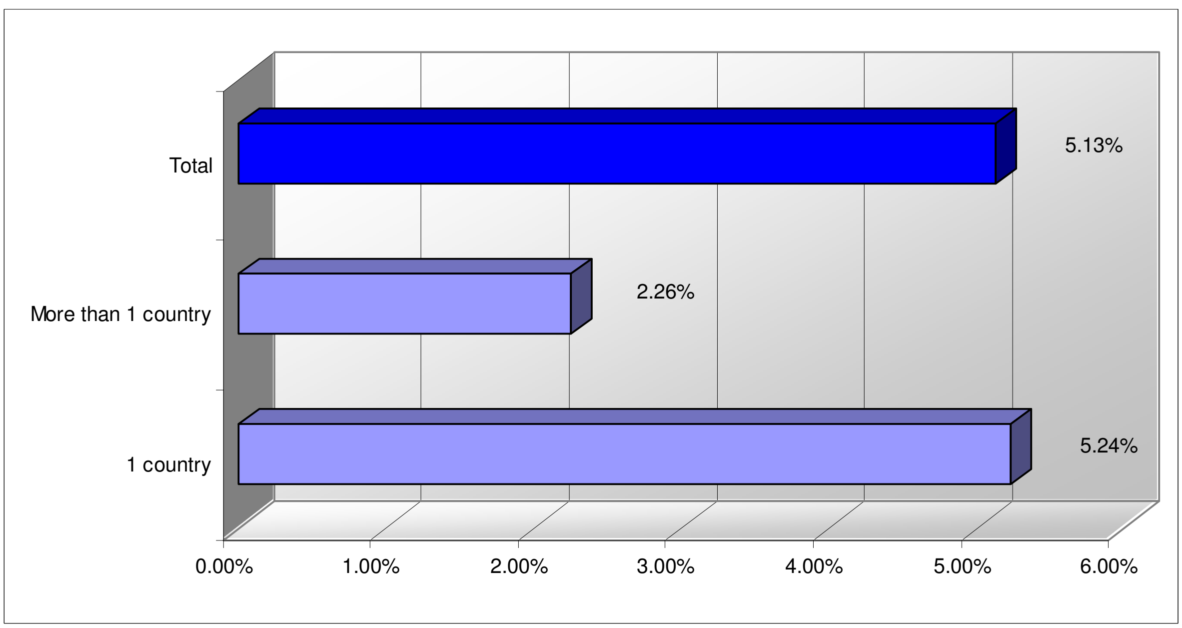


Figure A. 3 Share of new firms by country of the applicants

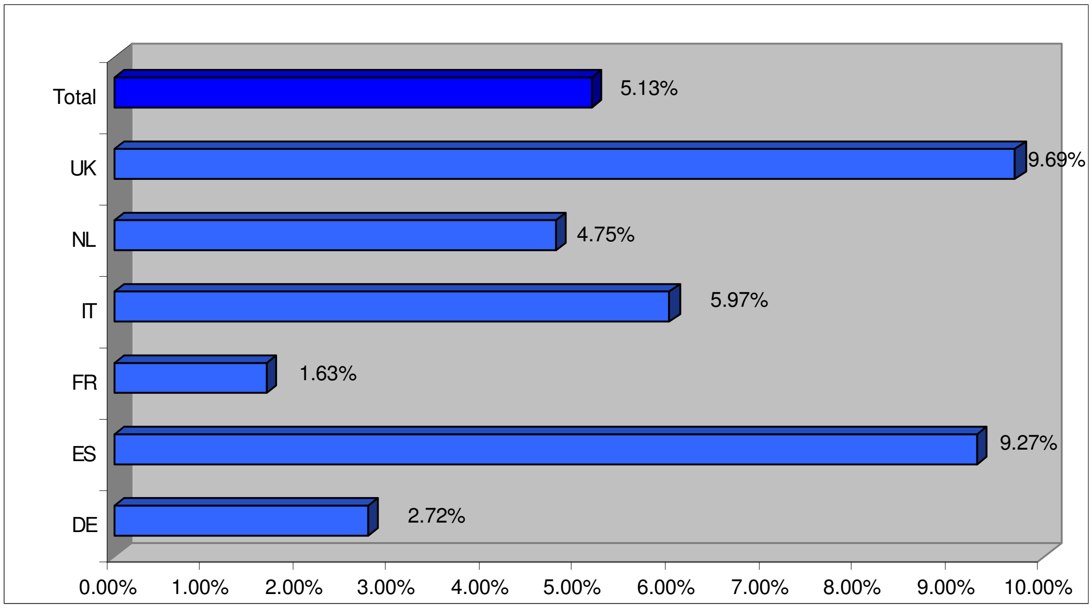
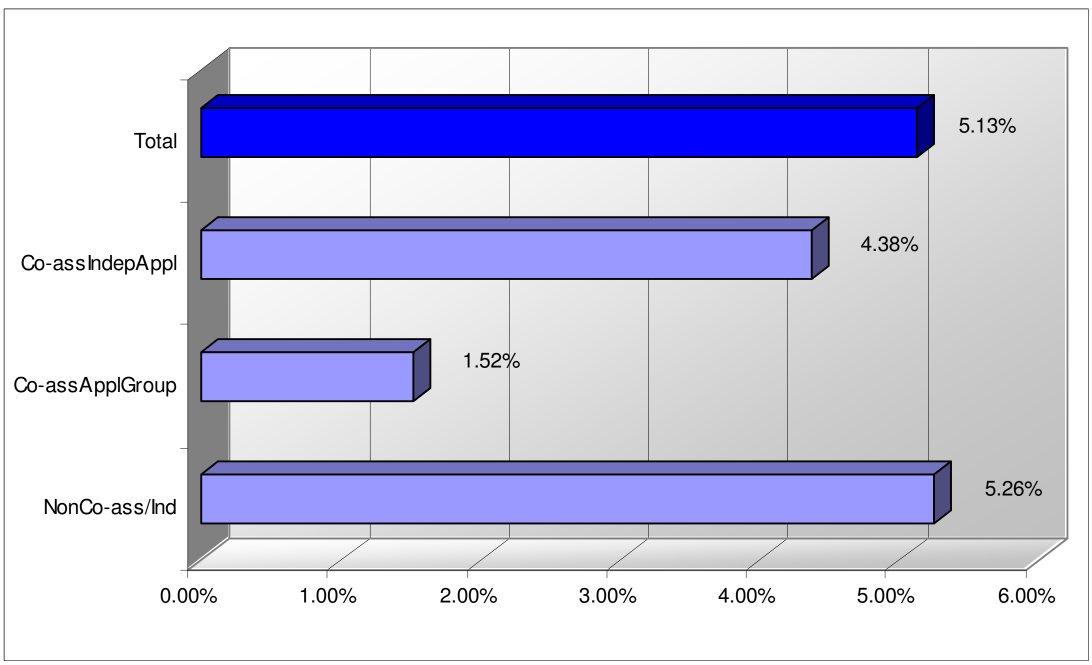


Figure A. 4 Share of new firms by nationality of the applicants



A III.4 Collaboration, Spillovers and the Sources of Knowledge in the Invention Process

The Tables in this section adds evidence on the importance and the type of collaborative links and knowledge spillovers that arose during the invention process leading to the PatVal-EU patents. Consistently with the structure of the Report, it looks at the collaboration among individual inventors; then, it goes into the type of collaborative links that the PatVal-EU inventors established with other partners to develop the innovation; third, it highlights the role of geographical proximity in fostering knowledge exchange among the inventors. Finally, it describes the sources of knowledge used to develop a patent.

Collaboration among inventors in the innovation process

Individual inventors often collaborate in teams of researchers to develop an innovation. By conditioning on the number of countries where the patent applicant was located, Table A.16 shows the share of patents produced by single inventors, as compared to the share of patents developed by a team of multiple inventors, either located within the same organization ("Internal Co-Inventors" or different organizations ("External Co- Inventors"). Table A.17 describes the affiliation of the inventors involved in the development of a patent. Table A.18 conditions on the micro technological class in which the patent is classified, and calculates the share of patents invented by single inventors, "Internal Co-Inventors" and "External Co- Inventors" in each micro technological class.

In Tables A.19 to A.23 we classify the patents as: (i) applied by single applicant or by an individual inventor; (ii) applied by multiple applicants all belonging to the same corporate group; (iii) applied by multiple applicants that do not belong to the same corporate group. Table A.19 shows the share of these three categories of patents by macro technological classes, while Table A.20 gives these shares by micro technological classes. Table A.21 looks at the share of patents in the three categories when the applicants are located in one country as compared to the case in which the applicants are located in more than one country. Table A.22 describes their European and non-European origins. Finally, Table A.23 shows the distribution of patents applied by single applicant, patents applied by multiple applicants belonging to the same corporate group, and patents applied by independent applicants by type of inventors' employer (i.e. large firms, medium-sized firms, small firms, private non-profit research institutions, public research organisations, universities, government laboratories, and other employers like the inventors themselves or other institutions).

Table A. 16 Affiliation of the inventors involved in the development of the patents. Number of applicant countries

	Patents developed with internal co-inventors	Patents developed with external co-inventors	Share of Individual inventors' patents	Total
1 country	47.78%	14.38%	37.84%	100.00%
More than 1 country	43.26%	33.69%	23.05%	100.00%
Total	47.63%	15.00%	37.36%	100.00%

Table A. 17 Affiliation of the inventors involved in the development of the patents. Domestic vs. foreign applicants.

	Patents developed with internal co-inventors	Patents developed with external co-inventors	Share of Individual inventors' patents	Total
Domestic applicant	47.83%	14.30%	37.87%	100.00%
European applicant	47.58%	16.18%	36.23%	100.00%
USA applicant	46.77%	14.77%	38.46%	100.00%
Non-EU & non-USA applicant	51.35%	8.11%	40.54%	100.00%
Non-domestic co-applicant	42.48%	34.59%	22.93%	100.00%
Total	47.63%	15.00%	37.37%	100.00%

Table A. 18 Collaboration among inventors. Distribution by "micro" technological class.

ISI Technological Classes	Patents developed with internal co-inventors	Patents developed with external co-inventors	Share of Individual inventors' patents	Total
Electrical Devices, Electrical Eng. & Electrical Energy	47.05%	12.56%	40.39%	100.00%
Audio-visual Technology	46.82%	12.14%	41.04%	100.00%
Telecommunications	52.00%	9.45%	38.55%	100.00%
Information Technology	49.23%	14.36%	36.41%	100.00%
Semiconductors	59.26%	9.88%	30.86%	100.00%
Optics	59.64%	13.25%	27.11%	100.00%
Analysis, Measurement, & Control Technology	42.77%	17.34%	39.88%	100.00%
Medical Technology	33.18%	22.27%	44.55%	100.00%
Organic Fine Chemistry	73.73%	18.76%	7.50%	100.00%
Macromolecular Chemistry & Polymers	70.69%	18.79%	10.51%	100.00%
Pharmaceuticals & Cosmetics	55.09%	24.55%	20.36%	100.00%
Biotechnology	54.41%	30.88%	14.71%	100.00%
Materials & Metallurgy	52.01%	27.18%	20.81%	100.00%
Agriculture, & Food Chemistry	47.75%	23.42%	28.83%	100.00%
Chemical & Petrol Industry, Basic Materials Chemistry	61.90%	15.31%	22.79%	100.00%
Chemical Engineering	47.54%	15.14%	37.32%	100.00%
Surface Technology & Coating	57.14%	15.04%	27.82%	100.00%
Materials Processing, Textiles & Paper	50.00%	13.62%	36.38%	100.00%
Thermal Processes & Apparatus	34.76%	10.16%	55.08%	100.00%
Environmental Technology	47.52%	21.99%	30.50%	100.00%
Machine Tools	38.56%	12.09%	49.35%	100.00%
Engines, Pumps & Turbines	43.03%	13.15%	43.82%	100.00%
Mechanical Elements	40.48%	12.60%	46.92%	100.00%
Handling & Printing	39.05%	11.49%	49.46%	100.00%
Agricultural & Food Processing, Machinery & Apparatus	34.01%	14.21%	51.78%	100.00%
Transport	41.08%	14.73%	44.19%	100.00%
Nuclear Engineering	46.34%	14.63%	39.02%	100.00%
Space Technology Weapons	58.18%	3.64%	38.18%	100.00%
Consumer Goods & Equipment	34.67%	11.11%	54.22%	100.00%
Civil Eng., Building & Mining	32.79%	10.66%	56.56%	100.00%
Total	47.63%	15.00%	37.37%	100.00%

Table A. 19 Number of applicant institutions in a patent. Distribution by "macro" technological class

	Single Applicant	Multiple Appl. Group	Multiple Appl. Indep.	Total
Electrical Engineering	93.12%	3.86%	3.02%	100.00%
Instruments	93.37%	2.85%	3.77%	100.00%
Chemical & Pharmaceutical tech.	91.61%	4.73%	3.65%	100.00%
Process Engineering	94.71%	1.51%	3.78%	100.00%
Mechanical Engineering	95.13%	1.26%	3.61%	100.00%
Total	93.86%	2.55%	3.58%	100.00%

Table A. 20 Number of applicant institutions in a patent. Distribution by "micro" technological class

ISI Technological Classes	Single Applicant	Multiple Appl. Group	Multiple Appl. Indep.	Total
Electrical Devices, Electrical Eng. & Electrical Energy	95.28%	2.23%	2.50%	100.00%
Audio-visual Technology	89.20%	7.73%	2.76%	100.00%
Telecommunications	91.26%	6.56%	2.30%	100.00%
Information Technology	92.46%	3.32%	3.79%	100.00%
Semiconductors	91.86%	2.22%	6.67%	100.00%
Optics	88.76%	9.20%	2.87%	100.00%
Analysis, Measurement, & Control Technology	94.04%	1.94%	4.05%	100.00%
Medical Technology	95.28%	0.00%	4.98%	100.00%
Organic Fine Chemistry	92.53%	2.75%	4.98%	100.00%
Macromolecular Chemistry & Polymers	96.33%	1.48%	2.11%	100.00%
Pharmaceuticals & Cosmetics	91.28%	3.76%	5.38%	100.00%
Biotechnology	95.71%	0.00%	6.17%	100.00%
Materials & Metallurgy	90.58%	2.92%	6.71%	100.00%
Agriculture, & Food Chemistry	80.87%	12.30%	5.74%	100.00%
Chemical & Petrol Industry, Basic Materials Chemistry	86.00%	11.15%	2.62%	100.00%
Chemical Engineering	93.79%	0.62%	6.21%	100.00%
Surface Technology & Coating	94.85%	0.70%	4.23%	100.00%
Materials Processing, Textiles & Paper	96.30%	0.59%	3.15%	100.00%
Thermal Processes & Apparatus	96.34%	2.29%	0.92%	100.00%
Environmental Technology	92.41%	0.00%	7.19%	100.00%
Machine Tools	97.16%	0.30%	2.42%	100.00%
Engines, Pumps & Turbines	94.53%	1.53%	3.83%	100.00%
Mechanical Elements	94.10%	1.45%	4.11%	100.00%
Handling & Printing	95.59%	1.92%	2.47%	100.00%
Agricultural & Food Processing, Machinery & Apparatus	97.03%	1.82%	0.91%	100.00%
Transport	94.58%	0.60%	4.47%	100.00%
Nuclear Engineering	92.86%	4.00%	6.00%	100.00%
Space Technology Weapons	96.49%	1.35%	1.35%	100.00%
Consumer Goods & Equipment	95.73%	2.18%	1.98%	100.00%
Civil Eng., Building & Mining	94.27%	0.48%	5.00%	100.00%
Total	93.86%	2.44%	3.66%	100.00%

Table A. 21 Number of applicant institutions in a patent. Number of applicant countries

	Single applicant	Multiple Appl. Group	Multiple Appl. Indep.	Total
1 country	96.99%	0.45%	2.56%	100.00%
More than 1 country	1.69%	64.53%	33.78%	100.00%
Total	93.86%	2.55%	3.58%	100.00%

Table A. 22 Number of applicant institutions in a patent. Domestic vs. foreign applicants

	Single Applicant	Multiple Appl. Group	Multiple Appl. Indep.	Total
Domestic applicant	96.76%	0.49%	2.75%	100.00%
European applicant	95.39%	3.00%	1.61%	100.00%
USA applicant	99.70%	0.00%	0.30%	100.00%
Non-EU & non-USA applicant	97.44%	0.00%	2.56%	100.00%
Non-domestic co-applicant	1.79%	63.80%	34.41%	100.00%
Total	93.86%	2.55%	3.58%	100.00%

Table A. 23 Number of applicant institutions in a patent. Distribution by type of inventors' employer

	Single Applicant	Multiple Appl. Group	Multiple Appl. Indep.	Total
Large companies	93.29%	3.41%	3.30%	100.00%
Medium sized companies	95.74%	0.52%	3.74%	100.00%
Small companies	96.70%	0.41%	2.89%	100.00%
Private Research Institutions	91.04%	1.49%	7.46%	100.00%
Public Research Institutions	86.19%	0.00%	13.81%	100.00%
Universities	93.66%	0.70%	5.63%	100.00%
Other Governm. Institutions	100.00%	0.00%	0.00%	100.00%
Others	94.92%	1.69%	3.39%	100.00%
Total	93.85%	2.55%	3.60%	100.00%

Formal and informal collaborations in research

This section adds empirical evidence on the extent of collaboration among different institutions to develop a patent. Tables A.24 to A.27 look at formal vs. informal collaborations. Table A.24 shows the share of collaborative patents developed in each micro technological class, and indicates the distribution of such collaborations between formal and informal collaborations. Table A.25 gives these shares by type of inventors' employer. Table A.26 shows the extent of formal and informal collaborations among institutions when the applicants are located in one country as compared to the case in which the applicants are located in more than one country, and Table A.27 describes the European and non-European origins of the applicants who collaborate to develop a patent.

Tables A.28 to A.30 focus on formal collaborations and classify the patents according to the type of organization to which the external inventors involved in the collaboration are affiliated (i.e. large companies, medium sized companies, small companies, private research institutions, Universities, and "others" as a residual category). Table A.28 shows the share of patents invented in collaboration with different external partners when the applicants are located in one country as compared to the case in which the applicants are located in more than one country, while Table A.29 describes the distribution of collaborations within different type of partners by the European and non-European origins of the patent applicant. Finally, Table A.30 gives the same distribution by conditioning on the micro technological class in which the patents are classified.

Table A. 24 Formal vs. Informal collaboration amongst institutions. Distribution by "micro" technological class

ISI Technological Classes	Share of "collaborative" patents	Share of formal collaborations	Share of informal collaborations
Electrical Devices, Electrical Eng. & Electrical Energy	17.34%	76.70%	23.30%
Audio-visual Technology	18.07%	73.33%	26.67%
Telecommunications	17.29%	69.05%	30.95%
Information Technology	21.08%	94.12%	5.88%
Semiconductors	18.82%	78.57%	21.43%
Optics	16.36%	76.00%	24.00%
Analysis, Measurement, & Control Technology	24.27%	80.17%	19.83%
Medical Technology	35.55%	69.01%	30.99%
Organic Fine Chemistry	20.34%	87.38%	12.62%
Macromolecular Chemistry & Polymers	20.97%	74.70%	25.30%
Pharmaceuticals & Cosmetics	23.46%	78.79%	21.21%
Biotechnology	39.13%	100.00%	0.00%
Materials & Metallurgy	29.55%	79.75%	20.25%
Agriculture, & Food Chemistry	35.14%	89.19%	10.81%
Chemical & Petrol Industry, Basic Materials Chemistry	17.87%	81.63%	18.37%
Chemical Engineering	23.47%	83.87%	16.13%
Surface Technology & Coating	24.24%	79.31%	20.69%
Materials Processing, Textiles & Paper	20.09%	76.25%	23.75%
Thermal Processes & Apparatus	24.44%	72.50%	27.50%
Environmental Technology	28.67%	86.49%	13.51%
Machine Tools	14.77%	83.72%	16.28%
Engines, Pumps & Turbines	15.85%	60.00%	40.00%
Mechanical Elements	14.85%	61.70%	38.30%
Handling & Printing	17.21%	79.05%	20.95%
Agricultural & Food Processing, Machinery & Apparatus	18.68%	72.73%	27.27%
Transport	18.35%	64.65%	35.35%
Nuclear Engineering	29.73%	77.78%	22.22%
Space Technology Weapons	23.08%	72.73%	27.27%
Consumer Goods & Equipment	18.45%	67.65%	32.35%
Civil Eng., Building & Mining	19.60%	72.13%	27.87%
Total	20.53%	76.88%	23.12%

Number of observations: 8499.

Table A. 25 Formal vs. Informal collaboration amongst institutions. Distribution by type of employer

	Share of "collaborative" patents	Share of formal collaborations	Share of informal collaborations
Large companies	16.61%	75.39%	24.61%
Medium sized companies	21.18%	76.39%	23.61%
Small companies	23.92%	74.48%	25.52%
Private Research Institutions	38.98%	71.43%	28.57%
Public Research Institutions	48.55%	88.89%	11.11%
Universities	56.12%	84.67%	15.33%
Other Governm. Institutions	23.08%	100.00%	0.00%
Others	23.53%	90.91%	9.09%
Total	20.16%	77.06%	22.94%

Number of observations: 8314

Table A. 26 Formal vs. Informal collaboration amongst institutions. Number of applicant countries.

	Share of "collaborative" patents	Share of formal collaborations	Share of informal collaborations
1 country	19.91%	76.41%	23.59%
More than 1 country	38.16%	84.00%	16.00%
Total	20.52%	76.88%	23.12%

Number of observations: 8498

Table A. 27 Formal vs. Informal collaboration amongst institutions. Domestic vs. foreign applicants.

	Share of "collaborative" patents	Share of formal collaborations	Share of informal collaborations
Domestic applicant	19.65%	76.45%	23.55%
European applicant	22.51%	84.78%	15.22%
USA applicant	22.15%	69.70%	30.30%
Non-EU & non-USA applicant	23.08%	37.50%	62.50%
Non-domestic co-applicant	39.85%	83.51%	16.49%
Total	20.53%	76.88%	23.12%

Number of observations: 8499

Table A. 28 Formal collaborations. Affiliation of the co-inventors involved in the development of the patents. Number of applicant countries.

	Affiliation of the "external" co-inventors					
	Large companies	Medium sized	Small companies	Private Res. Institutions	Universities	"Others"
1 country	49.07%	7.82%	20.89%	6.22%	16.27%	8.80%
More than 1 country	59.09%	11.36%	13.64%	0.00%	6.82%	6.82%
Total	49.79%	8.08%	20.36%	5.77%	15.58%	8.66%

Number of observations: 1213

Table A. 29 Formal collaborations. Affiliation of the co-inventors involved in the development of the patents. Domestic vs. foreign applicants.

	Affiliation of the "external" co-inventors					
	Large companies	Medium sized	Small companies	Private Res. Institutions	Universities	"Others"
Domestic applicant	48.44%	8.01%	21.88%	6.74%	16.21%	8.89%
European applicant	53.33%	8.33%	10.00%	1.67%	16.67%	6.67%
USA applicant	64.29%	2.38%	9.52%	0.00%	16.67%	9.52%
Non-EU & non-USA applicant	50.00%	0.00%	50.00%	0.00%	0.00%	0.00%
Non-domestic co-applicant	56.47%	11.76%	14.12%	0.00%	7.06%	7.06%
Total	49.79%	8.08%	20.36%	5.77%	15.58%	8.66%

Number of observations: 1213

Table A. 30 Formal collaborations. Affiliation of the inventors involved in the development of the patents. Distribution by "micro" technological class in %

ISI Technological Classes	Affiliation of the "external" co-inventors					
	Large companies	Medium sized	Small companies	Private Res. Institutions	Universities	"Others"
Electrical Devices, Electrical Eng. & Electrical Energy	57.14%	7.79%	15.58%	6.49%	14.29%	3.90%
Audio-visual Technology	42.86%	0.00%	42.86%	4.76%	19.05%	9.52%
Telecommunications	40.00%	8.00%	16.00%	12.00%	16.00%	24.00%
Information Technology	44.00%	12.00%	12.00%	4.00%	36.00%	4.00%
Semiconductors	42.86%	14.29%	42.86%	28.57%	28.57%	0.00%
Optics	42.86%	0.00%	28.57%	9.52%	4.76%	19.05%
Analysis, Measurement, & Control Technology	37.65%	8.24%	31.76%	3.53%	17.65%	7.06%
Medical Technology	21.28%	8.51%	34.04%	6.38%	23.40%	23.40%
Organic Fine Chemistry	42.11%	8.42%	13.68%	10.53%	31.58%	2.11%
Macromolecular Chemistry & Polymers	62.65%	2.41%	10.84%	4.82%	24.10%	2.41%
Pharmaceuticals & Cosmetics	60.53%	0.00%	10.53%	7.89%	21.05%	5.26%
Biotechnology	23.81%	0.00%	14.29%	23.81%	28.57%	9.52%
Materials & Metallurgy	58.44%	7.79%	18.18%	6.49%	19.48%	6.49%
Agriculture, & Food Chemistry	34.62%	11.54%	15.38%	7.69%	19.23%	15.38%
Chemical & Petrol Industry, Basic Materials Chemistry	62.50%	7.50%	5.00%	7.50%	17.50%	2.50%
Chemical Engineering	37.50%	15.00%	22.50%	5.00%	17.50%	12.50%
Surface Technology & Coating	47.37%	10.53%	10.53%	10.53%	0.00%	15.79%
Materials Processing, Textiles & Paper	53.45%	10.34%	24.14%	5.17%	10.34%	6.90%
Thermal Processes & Apparatus	50.00%	11.11%	16.67%	11.11%	16.67%	11.11%
Environmental Technology	43.33%	3.33%	33.33%	6.67%	26.67%	6.67%
Machine Tools	45.16%	3.23%	38.71%	3.23%	9.68%	16.13%
Engines, Pumps & Turbines	66.67%	9.09%	12.12%	0.00%	0.00%	12.12%
Mechanical Elements	59.52%	9.52%	23.81%	2.38%	7.14%	7.14%
Handling & Printing	67.69%	13.85%	15.38%	0.00%	1.54%	1.54%
Agricultural & Food Processing, Machinery & Apparatus	44.00%	4.00%	28.00%	0.00%	4.00%	20.00%
Transport	65.82%	10.13%	17.72%	2.53%	2.53%	12.66%
Nuclear Engineering	60.00%	0.00%	20.00%	0.00%	20.00%	0.00%
Space Technology Weapons	0.00%	0.00%	0.00%	0.00%	100.00%	0.00%
Consumer Goods & Equipment	34.88%	11.63%	20.93%	2.33%	6.98%	18.60%
Civil Eng., Building & Mining	38.89%	13.89%	36.11%	5.56%	5.56%	5.56%
Total	49.79%	8.08%	20.36%	5.77%	15.58%	8.66%

The role of geographical proximity for collaboration

The Tables in this part of Annex III provide descriptive statistics on the role of geographical proximity for fostering collaborations among inventors. Like in Section 3.5 we distinguish among 4 types of interactions: (1) interactions with people internal to the inventor's organization, and geographically close (i.e. less than one hour to reach physically the partner); (2) interactions with people internal to the inventor's organization, and geographically distant (i.e. more than one hour to reach physically the partner); (3) interactions with people external to the inventor's organization, and geographically close; (4) interactions with people external to the inventor's organization, and geographically distant. By using a scale from 1 to 5 Table A.32 shows the importance of these four types of interactions in the European regions in which the importance of close and external interactions for developing innovations is below the EU6 average. Table A.32 shows the importance of the four types of interactions in each micro technological class in which the PatVal-EU patents are classified. Table A.33 describes their importance when the applicants are located in one country as compared to the case in which the applicants are located in more than one country. Table A.34 looks at the importance of the four forms of interaction according to the European and non-European origins of the applicants.

Table A. 31 Importance of the interaction with other people while developing the innovation. Distribution by European regions (NUTS2)

Country	NUTS 2	Close & Internal	Distant & Internal	Close & External	Distant & External	N
Total		3.02 (1.88)	1.31 (1.70)	0.88 (1.45)	1.32 (1.77)	8588
UK	Hampshire and Isle of Wight	3.40 (1.80)	1.30 (1.79	0.87 (1.51)	1.92 (2.10)	52
NL	Noord-Holland	3.17 (1.81)	1.32 (1.76)	0.87 (1.47)	1.21 (1.79)	117
NL	Gelderland	3.18 (1.95)	1.12 (1.59)	0.83 (1.38)	1.53 (1.81)	129
NL	Noord-Brabant	3.38 (1.86)	1.29 (1.61	0.82 (1.42)	1.29 (1.70)	337
NL	Overijssel	3.06 (2.06)	0.81 (1.37)	0.82 (1.42)	1.19 (1.80)	62
DE	Gießen	2.11 (1.94)	0.76 (1.38)	0.81 (1.61)	1.35 (1.87)	37
DE	Hannover	2.80 (1.89)	1.03 (1.57)	0.81 (1.40)	1.77 (1.96)	86
DE	Koblenz	2.52 (2.00)	1.42 (1.78)	0.77 (1.41)	1.00 (1.67)	31
DE	Karlsruhe	3.17 (1.89)	1.15 (1.55)	0.77 (1.33)	1.64 (1.85)	143
DE	Oberbayern	2.95 (1.91)	1.04 (1.47)	0.77 (1.33)	1.07 (1.62)	333
UK	Cheshire	3.53 (1.68)	1.74 (1.88)	0.77 (1.09)	1.40 (1.79)	51
DE	Mittelfranken	2.73 (1.95)	0.90 (1.43)	0.75 (1.40)	1.57 (1.94)	134
UK	West Yorkshire	3.33 (1.87)	1.40 (1.62)	0.75 (1.10)	1.25 (1.61)	57
DE	Freiburg	2.62 (1.89)	1.26 (1.68)	0.74 (1.35)	1.42 (1.80)	86
DE	Detmold	3.00 (1.80)	1.09 (1.34)	0.73 (1.13)	0.73 (1.40)	44
DE	Münster	2.95 (2.00)	0.80 (1.19)	0.72 (1.37)	1.15 (1.76)	60
DE	Köln	3.09 (1.82)	1.39 (1.75)	0.72 (1.33)	1.13 (1.71)	213
ES	Cataluña	3.66 (1.76)	3.05 (2.12)	0.71 (1.50)	0.76 (1.47)	101
NL	Limburg	3.75 (1.59)	1.00 (1.55)	0.70 (1.36)	1.46 (1.93)	114
DE	Hamburg	2.86 (1.83)	1.27 (1.79)	0.70 (1.28)	1.08 (1.60)	50
DE	Braunschweig	2.03 (1.96)	0.70 (1.32)	0.67 (1.40)	1.63 (1.96)	30
IT	Veneto	2.40 (1.95)	1.25 (1.90)	0.67 (1.28)	1.29 (1.79)	97
DE	Darmstadt	3.03 (1.83)	1.09 (1.54)	0.67 (1.22)	1.13 (1.68)	352
IT	Piemonte	2.57 (1.84)	1.27 (1.62)	0.66 (1.27)	1.14 (1.74)	188
UK	Surrey, east and west Sussex	3.17 (2.03)	2.14 (2.08)	0.65 (1.27)	1.42 (1.91)	90
FR	Bretagne	2.83 (1.91)	1.20 (1.71)	0.63 (1.07)	1.20 (1.65)	30
UK	Greater Manchester	3.72 (1.70)	1.81 (1.88)	0.62 (1.10)	1.51 (1.98)	78
DE	Tübingen	2.57 (1.92)	1.13 (1.50)	0.61 (1.22)	1.15 (1.65)	122
DE	Stuttgart	2.89 (1.92)	1.03 (1.48)	0.61 (1.22)	1.17 (1.75)	336
DE	Rheinhessen-Pfalz	3.61 (1.64)	0.99 (1.50)	0.61 (1.15)	0.83 (1.39)	190
DE	Berlin	2.97 (1.88)	1.08 (1.76)	0.58 (1.22)	1.66 (2.06)	64
IT	Emilia-Romagna	2.34 (1.94)	1.10 (1.68)	0.58 (1.13)	0.84 (1.42)	154
UK	Herefordshire, Worcestershire and Warks	3.57 (1.87)	2.16 (2.28)	0.56 (0.94)	2.10 (2.02)	44
IT	Friuli-Venezia Giulia	2.29 (1.95)	1.02 (1.48)	0.54 (1.16)	0.85 (1.34)	69
IT	Lazio	2.45 (1.95)	1.40 (1.87)	0.52 (1.02)	1.07 (1.64)	33
DE	Oberpfalz	2.70 (1.89)	0.83 (1.37)	0.51 (1.16)	0.91 (1.60)	47
UK	Essex	3.29 (1.69)	1.54 (1.99)	0.50 (1.24)	1.31 (1.94)	41
IT	Lombardia	2.64 (1.94)	1.08 (1.63)	0.49 (1.13)	1.02 (1.69)	392
DE	Arnsberg	2.53 (1.91)	0.70 (1.30)	0.47 (1.10)	1.05 (1.65)	96
UK	Kent	3.58 (1.70)	1.68 (1.82)	0.44 (0.88)	1.15 (1.70)	45
DE	Schwaben	2.42 (1.94)	0.80 (1.45)	0.41 (1.01)	1.16 (1.78)	83
ES	Pais Vasco	3.30 (1.70)	2.48 (2.21)	0.36 (1.06)	0.82 (1.47)	30
IT	Toscana	2.42 (1.98)	1.00 (1.56)	0.31 (0.89)	0.97 (1.68)	50

Note: This Table includes the European regions in which the importance of Close & External interactions are below the EU6 average and the number of observation in each region is ≥30.

Table A. 32 Importance of the interaction with other people while developing the innovation. Distribution by "micro" technological class

ISI Technological Classes	Close Internal	Distant Internal	Close External	Distant External
Electrical Devices, Electrical Eng. & Electrical Energy	3.04 (1.83)	1.34 (1.69)	0.80(1.34)	1.31 (1.77)
Audio-visual Technology	3.02 (1.93)	1.03 (1.58)	0.70 (1.38)	0.86 (1.46)
Telecommunications	3.36 (1.69)	1.42 (1.72)	0.76 (1.40)	1.22 (1.73)
Information Technology	3.47 (1.73)	1.45 (1.68)	0.84 (1.39)	1.41 (1.78)
Semiconductors	3.71 (1.54)	1.27 (1.51)	1.10 (1.53)	1.53 (1.59)
Optics	3.36 (1.74)	1.28 (1.64)	0.93 (1.43)	1.25 (1.68)
Analysis, Measurement, & Control Technology	2.94 (1.87)	1.26 (1.67)	0.86 (1.47)	1.37 (1.80)
Medical Technology	2.67 (1.99)	1.40 (1.71)	1.10 (1.59)	2.02 (1.95)
Organic Fine Chemistry	3.56 (1.69)	1.39 (1.76)	0.75 (1.35)	1.00 (1.59)
Macromolecular Chemistry & Polymers	3.45 (1.77)	1.56 (1.76)	0.88 (1.44)	1.35 (1.78)
Pharmaceuticals & Cosmetics	2.87 (1.84)	1.13 (1.61)	0.90 (1.42)	1.44 (1.81)
Biotechnology	3.19 (1.94)	1.28 (1.64)	1.00 (1.61)	1.46 (1.80)
Materials & Metallurgy	3.19 (1.84)	1.50 (1.80)	1.27 (1.72)	1.74 (1.89)
Agriculture, & Food Chemistry	3.06 (1.86)	1.65 (1.87)	0.80 (1.39)	1.51 (1.85)
Chemical & Petrol Industry, Basic Materials Chemistry	3.50 (1.70)	1.56 (1.82)	0.83 (1.41)	1.18 (1.72)
Chemical Engineering	2.89 (1.88)	1.16 (1.64)	0.87 (1.49)	1.16 (1.71)
Surface Technology & Coating	3.20 (1.88)	1.60 (1.93)	0.73 (1.37)	1.61 (1.94)
Materials Processing, Textiles & Paper	3.03 (1.95)	1.27 (1.74)	0.84 (1.45)	1.46 (1.89)
Thermal Processes & Apparatus	2.81 (1.93)	1.00 (1.55)	0.64 (1.20)	1.39 (1.85)
Environmental Technology	2.89 (1.98)	1.25 (1.70)	1.00 (1.54)	1.32 (1.83)
Machine Tools	2.66 (1.87)	1.16 (1.59)	0.77 (1.32)	1.33 (1.78)
Engines, Pumps & Turbines	2.95 (1.88)	1.33 (1.61)	0.73 (1.29)	1.25 (1.70)
Mechanical Elements	2.97 (1.87)	1.06 (1.55)	0.90 (1.47)	1.28 (1.73)
Handling & Printing	2.76 (1.93)	1.17 (1.64)	0.85 (1.39)	1.23 (1.73)
Agricultural & Food Processing, Machinery & Apparatus	2.73 (1.94)	1.30 (1.76)	1.02 (1.53)	1.47 (1.81)
Transport	2.95 (1.89)	1.36 (1.72)	0.88 (1.45)	1.35 (1.77)
Nuclear Engineering	2.39 (2.00)	1.32 (1.78)	0.97 (1.58)	1.53 (1.87)
Space Technology Weapons	2.78 (1.89)	1.51 (1.76)	1.07 (1.66)	1.36 (1.84)
Consumer Goods & Equipment	2.70 (1.99)	1.29 (1.78)	1.04 (1.62)	1.16 (1.72)
Civil Eng., Building & Mining	2.46 (1.99)	1.17 (1.63)	1.08 (1.56)	1.24 (1.72)
Total	3.02 (1.88)	1.31 (1.70)	0.88 (1.45)	1.32 (1.77)

Note: standard deviations in parenthesis.

Table A. 33 Importance of the interaction with other people while developing the innovation. Number of applicant countries.

	1 country	More than 1 country	**Total**
Close Internal	3.00 (1.89)	3.51 (1.61)	3.02 (1.88)
Distant Internal	1.29 (1.69)	1.82 (1.89)	1.31 (1.70)
Close External	0.88 (1.45)	0.99 (1.52)	0.88 (1.45)
Distant External	1.32 (1.77)	1.48 (1.82)	1.32 (1.77)

Note: standard deviations in parenthesis.

Table A. 34 Importance of the interaction with other people while developing the innovation. Domestic vs. foreign applicants.

	Domestic applicant	European applicant	USA applicant	Non-EU & non-USA applicant	Non-domestic co-applicant	Total
Close Internal	2.99 (1.89)	3.05 (1.89)	3.19 (1.85)	3.22 (1.71)	3.51 (1.59)	3.02 (1.88)
Distant Internal	1.23 (1.66)	1.89 (1.86)	2.01 (1.95)	1.82 (1.93)	1.76 (1.86)	1.31 (1.70)
Close External	0.88 (1.45)	0.88 (1.43)	0.83 (1.44)	0.83 (1.40)	1.04 (1.56)	0.88 (1.45)
Distant External	1.31 (1.77)	1.40 (1.79)	1.25 (1.76)	1.31 (1.73)	1.54 (1.83)	1.32 (1.77)

Note: standard deviations in parenthesis.

The Sources of Knowledge

Table A.35 and Table A.36 look at the sources of knowledge used to develop the patented innovation (i.e. knowledge developed in university and non-university laboratories, the scientific literature, the participation in conferences and workshops, earlier patents, the firm's users, suppliers and competitors). They use a scale from 1 to 5 to measure their importance. Table A.30 shows the importance of these sources of knowledge when the patents' applicants are located in one country as compared to the case in which they are located in more than one country. Table A.31 describes their importance according to the European and non-European origins of the patents' applicants.

Table A. 35 Importance of different sources of knowledge. Number of applicant countries.

	1 country	More than 1 country	Total
Laboratories	1.35 (1.74)	1.45 (1.68)	1.35 (1.74)
Scientific literature	2.54 (1.89)	2.81 (1.80)	2.55 (1.89)
Conferences	1.67 (1.72)	1.83 (1.71)	1.67 (1.72)
Patents	2.60 (1.90)	2.78 (1.85)	2.60 (1.90)
Users	2.89 (1.98)	2.65 (1.97)	2.88 (1.98)
Suppliers	1.54 (1.73)	1.69 (1.73)	1.55 (1.73)
Competitors	2.16 (1.88)	1.98 (1.81)	2.15 (1.87)

Note: standard deviations in parenthesis.

Table A. 36 Importance of different sources of knowledge. Domestic vs. foreign applicants.

	Domestic applicant	European applicant	USA applicant	Non-EU & non-USA applicant	Non-domestic co-applicant	Total
Laboratories	1.36 (1.75)	1.33 (1.73)	1.11 (1.65)	1.23 (1.77)	1.49 (1.68)	1.35 (1.74)
Scientific literature	2.55 (1.89)	2.65 (1.87)	2.32 (1.87)	3.05 (1.90)	2.80 (1.78)	2.55 (1.89)
Conferences	1.67 (1.72)	1.65 (1.71)	1.49 (1.68)	2.23 (2.03)	1.87 (1.71)	1.67 (1.72)
Patents	2.59 (1.90)	2.69 (1.93)	2.58 (1.93)	2.79 (1.94)	2.79 (1.83)	2.60 (1.90)
Users	2.88 (1.98)	3.04 (1.96)	2.89 (1.98)	2.00 (2.01)	2.68 (1.97)	2.88 (1.98)
Suppliers	1.54 (1.73)	1.50 (1.73)	1.61 (1.70)	1.23 (1.71)	1.74 (1.73)	1.55 (1.73)
Competitors	2.18 (1.87)	1.93 (1.90)	1.81 (1.85)	1.77 (1.77)	2.04 (1.80)	2.15 (1.87)

Note: standard deviations in parentheses.