Everything you Always Wanted to Know About Inventors (But Never Asked):
Evidence from the PatVal-EU Survey

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with the contribution of all PatVal-EU researchers

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Abstract

By drawing information from a survey of inventors of 9,017 European patents (PatVal-EU), this paper provides novel and detailed data about the characteristics of the European inventors, the sources of their knowledge, the importance of formal and informal collaborations among researchers and institutions, the motivations to invent, and the actual use and economic value of the patents. This is important information as the unavailability of direct indicators has limited the scope and depth of the empirical studies on innovation.

Acknowledgements

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1 Introduction

There is consensus in the literature about the importance of education, research and innovation for economic growth and development. As a matter of fact, a priority in the Lisbon Summit agenda was the transition of the EU towards a competitive and dynamic knowledge-based economy that is capable of sustainable economic growth. To do so, the Summit aimed at marking a turning point for the EU innovation policy in order to strengthen the EU research capacity, and to promote entrepreneurship and employment (European Commission, 2003a).

This paper focuses on a number of ingredients that determine the innovative performance of the European countries and their potentialities for economic growth. It provides information that is not available from other sources on the characteristics of the research inputs used to develop innovations in Europe – such as the characteristics of the inventors, the motivations to innovate, the sources of knowledge used in the innovation process – and it describes the use and the economic value of the European patents. Our data are drawn from a survey of 9,017 patents granted by the EPO with priority date in 1993-1997, and located in France, Germany, Italy, the Netherlands, Spain and the United Kingdom (hereafter the “EU6” countries).

There is a rich literature on innovation and the measurement of the R&D activities (for a survey see Griliches, 1990; Patel and Pavitt, 1995). Quite a few contributions study the R&D process by using input data such as the R&D expenditure and the human capital employed in research. An even larger number of studies use US and EU patent indicators to measure the R&D output over time, across firms and across countries (see Hall et al., 2001 for a survey). However, if patent indicators are fairly standard in the literature, they have a number of limitations as well (see, for example, Griliches, 1990).

This is the case, for example, of patent citations that the empirical literature has typically used to measure the importance and the “value” of the innovations (see, for example, Trajtenberg, 1990; Hall et al., 2005; Harhoff et al., 1999), or to describe the direction and geographical extent of knowledge flows among inventors and patent holders (Jaffe et al., 1993, Verspagen, 1997). The argument against the use of patent citations is that many citations are added by the patent examiners. Moreover, some of them are actually included after the innovation has been produced, and others are added just to avoid infringements. While Jaffe, Trajtenberg and Fogarty (2000) and Jaffe, Fogarty and Banks (1998) claim that patent citations are a good proxies for measuring knowledge spillovers, other studies go in the opposite direction and show that patent citations have serious limitations in measuring information flows (Almeida and Kogut, 1999; Singh, 2005; Breschi and Lissoni, 2005). For example, Alcacer and Gittelman (2004) show that the patent examiners add 40% of all citations and two-thirds of citations on the average US patent. About 40% of all patents have all citations added by the examiners (see also Harhoff et al., 2005, for EPO citations analysis).

In spite of this debate, during the past 20 years, the economic and managerial literature using patent indicators has been growing steadily. Moreover, a few patent surveys were also conducted to gather direct information on the innovation process and its outcome. This is the case of Harhoff and his colleagues who conducted a patent survey in the US and Germany to explore the
distribution of the economic value of patents (see, for example, Scherer and Harhoff, 2000; Harhoff, Scherer and Vopel, 2003b). The Yale survey (Levin et al. 1987) and the CMU survey (Cohen Nelson and Walsh, 2000) have investigated the motivations for patenting of US firms. Cohen et al. (2002) presented survey evidence on the role of patents for diffusing information in Japan relative to the US. Finally, Arundel and Steinmueller (1998) used the Community Innovation Survey to look at patents as information channels in Europe. While these surveys provide novel and direct data, they have limited European coverage and are mostly biased towards large companies.

The need for large-scale, cross-country and cross-sectoral specific information about the characteristics of the innovation process and the economic value of the innovations was precisely the motivation for carrying out the PatVal-EU survey. We designed it to collect direct and detailed information on these issues in different European countries and technological fields, and to solve the problems associated with the indirect indicators that the literature has typically used.

A second and related goal of the survey was to gather new data on other issues that the researchers could not study in depth because of the limited availability of information, including indirect indicators. Compared to previous surveys on patents, the PatVat-EU survey has a broad coverage in terms of the European countries surveyed, it deals with both private and public organizations that apply for an EPO patent, and it collects information on small, medium and large business companies. The results from the survey help also confirm or deny the validity of some “traditional” indirect measures.

This paper focuses on three research themes on which the availability of our data can improve significantly our knowledge.

First, there has been in recent years a renewed interest in studying inventors’ productivity (Narin and Breitzman, 1995; Ernst et al., 2000; Jones, 2005). Traditional contributions on this topic focus on academic scientists and they show that the distribution of productivity among individuals is very skewed (see, for example, Allison and Steward, 1974; Cole, 1979; Merton, 1968) and that it declines with age in a number of disciplines (see, for example, Levin and Stephan, 1991). Little is known, however, about inventors’ productivity, and the few existing studies focus on small samples of inventors in specific companies and countries because of the limited availability of information on individual inventors.

Second, there is an extensive literature on the existence of knowledge spillovers and the benefits to locate in a geographical cluster (e.g. Jaffe, 1986; Jaffe, Trajtenberg and Henderson, 1993; Audretsch and Feldman, 1996; Swann et al. 1998). However, apart from the debate on patent citations to measure knowledge spillovers, a limitation of these studies is that they do not explain the sources of such spillovers. The information on the affiliation of the inventors, the existence of formal and informal collaborations among them and their institutions, and the importance of geographical proximity for fostering the interaction in research is extremely rare, and it is available only for small samples (e.g. Balconi et al., 2004).

Third, there is a rising interest in understanding the strategic versus commercial motivations to patent, and the extent to which patents are used, and why they are not. Systematic empirical evidence, however, is weak on these issues. The empirical evidence shows that few patents yield
economic returns, while a large number is left unused, mainly because of strategic motivations (Hall and Ziedonis, 2001; Cohen, Nelson and Walsh, 2000; Shapiro, 2000; Rivette and Kline, 2000). Patent surveys explore these issues (i.e. the Yale and the CMU surveys), but they focus on large US companies with R&D labs, and they do not explore the actual use/no-use of the patents. Cross-country and cross-sectoral data are missing, and the existing contributions use small samples in specific industries with limited or no variation in patent strength (on firms’ licensing strategies see, for example, Grindley and Teece, 1997; Arora et al., 2001).

This paper is the first of a series of contributions based on the PatVal-EU survey to explore these issues. It starts by describing the characteristics of the principal actors of the innovation process (i.e. the inventors), their educational and professional background, their age, and the motivations they have to invent. It then looks at the process through which innovations are produced, including the setting up of research collaborations among inventors and institutions, and the mechanisms through which geographically localized knowledge spillovers enter the process. Finally, this paper describes the destiny of the EPO patents in terms of the monetary value they generate, the use made of them by the patent holders, and the role they play for entrepreneurship.

Section 2 describes the survey and the data we collected through the PatVal-EU questionnaire. Sections 3 to 5 are on the three themes mentioned above, and each section starts with a brief discussion of the existing literature. The final Section concludes and summarises the results. Annex 1 describes the methodology employed to perform the PatVal-EU survey, and Annex 2 focuses on a test we performed on the unbiasness answers given by the inventors.

2 The PatVal-EU survey

The objective of the PatVal-EU survey was to collect information on the economic value of the European patents, and on other aspects about the innovation process and its output that is not available from other sources. Specifically, we asked questions about the following issues:

*The inventors of the European patents.* We collected information on their age, educational and professional background, institutional affiliation, mobility across organisations and the rewards for inventing.

*The innovation process.* We interviewed the inventors about the sources of knowledge and their relative importance in the research project leading to the patent, the use of formal and informal collaborations, and the role of geographical proximity for the interaction among individuals. We also asked the inventors their best guess about the cost and time of the research that led to the patented innovation, the type of funding for the research, and the relationship between the patented innovation and previous innovations.

*Property rights and the economic value of patents.* We asked the inventors about the motivations for patenting and the actual use of the patent (i.e. whether it was used in licensing agreements, in industrial and commercial applications, or to start a new venture). The questionnaire also

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1 On the use of patents there is a survey for large Japanese firms (Nagaoka, 2003).
included questions about the inventors’ best estimate of the strategic and economic value of the patent both in categorical and monetary terms.

The full-scale PatVal-EU survey started in May 2003, and it ended in January 2004. It was directed to the inventors of 27,531 patents granted at the EPO with priority date in 1993-1997, and located in France, Germany, Italy, the Netherlands, Spain and the United Kingdom. Appendix 1 describes the details of the questionnaire, the sampling strategy, the pilot tests, the problems we faced during the survey, and the solutions we adopted.

In the end the European inventors responded to 9,216 questionnaires covering 9,017 patents, which is very close to the expected 10,000 responses. Table 1 shows the number of “contacted patents” (i.e. patents whose inventors received the questionnaire) and the final composition of the PatVal-EU sample by country: 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.

Table 1. The PatVal-EU Survey: targeted number of patents and response rates. Distribution by country.

<table>
<thead>
<tr>
<th></th>
<th>DE</th>
<th>ES</th>
<th>FR*</th>
<th>IT</th>
<th>NL</th>
<th>UK</th>
<th>EU6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of patents whose inventors were contacted</td>
<td>10,215</td>
<td>815</td>
<td>4,199</td>
<td>1,857</td>
<td>2,594</td>
<td>7,846</td>
<td>27,531</td>
</tr>
<tr>
<td>Number of patents for which the inventors responded</td>
<td>3,346</td>
<td>269</td>
<td>1,486</td>
<td>1,250</td>
<td>1,124</td>
<td>1,542</td>
<td>9,017</td>
</tr>
<tr>
<td>Response rate as the share of responses over the contacted patents</td>
<td>32.8%</td>
<td>33.0%</td>
<td>35.4%</td>
<td>67.3%</td>
<td>43.3%</td>
<td>19.7%</td>
<td>32.8%</td>
</tr>
<tr>
<td>Country share of patents in the final sample</td>
<td>37.1%</td>
<td>3.0%</td>
<td>16.5%</td>
<td>13.9%</td>
<td>12.5%</td>
<td>17.1%</td>
<td>100%</td>
</tr>
</tbody>
</table>

* As we shall see in Appendix 2, the French survey was directed to both the inventors and the applicant organisations. The response rate was 23.9% for the questionnaires sent to the applicants, and 13.9% for those sent both to the applicants and the inventors. This paper reports the French data on patent characteristics as provided by the inventors.

Table 2 describes the composition of the dataset by macro technological classes and affiliation of the inventors. The PatVal-EU patents are classified in 5 “macro” technological classes: Electrical engineering, Instruments, Chemicals & Pharmaceuticals, Process engineering, and Mechanical engineering. The survey also provides information about the type of inventors’ employers: small

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2 The number of questionnaires is larger than the number of surveyed patents because 192 patents were responded by more than one inventor. Since the statistics in the paper are based on the number of patents, we randomly eliminated multiple responses on the same patent. These multiple responses were used to check for the consistency of information provided by different inventors.

3 Country differences in the way the inventors could be approached determined different response rates. In the UK, for example, the fact that the phone books do not report the full first name of the inventors prevented us from checking whether the address listed in the patent corresponded to the place of residence of the inventors. This caused a response rate of 19.7%. At the opposite extreme, the Italian response rate was 67.3% because the questionnaires were sent only to the inventors with a correct address, and who accepted to participate in the survey. The Italian inventors were also called twice to remind to fill out the papers. In the Netherlands the effectiveness of the web-survey led to a response rate of 43.3%. The other countries had a response rate of about one-third, which is in line with most surveys.

4 We used the ISI-INIPI-OST classification system elaborated by the German Fraunhofer Institute of Systems and Innovation Research (ISI), the French Patent Office (INIPI) and the Observatoire des Science and des Techniques (OST). This classification distinguishes among 30 “micro” technological classes and 5 “macro” technology areas based on the International Patent Classification (IPC). For the concordance between ISI-INIPI-OST technological
firms (less than 100 employees), medium-sized firms (100-250), large firms (more than 250 employees), universities, public or private research institutions, and others.

The shares next to the technological classes (left-end column) show that Mechanical engineering and Process engineering are the most represented technologies at the EU6 level. As expected, the business sector, and in particular the large companies, are the most common source of innovations in all six countries, as it produces about 93% of all the PatVal-EU patents. Universities account for 3.2% patents in the sample, and the other Public Research Institutions for 2%. Moreover, there is diversity among the six countries in terms of the importance of the large vs. the small and medium firms in producing innovations. In particular, the German share of inventors employed in large companies is the largest (79.9%), compared to much smaller shares in France, Italy, the UK (all around 60-65%) and Spain (54%).

Table 2. Composition of the sample by “macro” technological classes and by type of inventors’ employers

<table>
<thead>
<tr>
<th></th>
<th></th>
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<th></th>
<th></th>
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<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Electrical Eng. (15.8%)*</td>
<td>79.9%</td>
<td>5.5%</td>
<td>9.1%</td>
<td>0.4%</td>
<td>1.8%</td>
<td>2.9%</td>
<td>0.1%</td>
<td>0.3%</td>
</tr>
<tr>
<td>Instruments (10.9%)</td>
<td>60.4%</td>
<td>7.9%</td>
<td>16.7%</td>
<td>3.2%</td>
<td>3.8%</td>
<td>7.0%</td>
<td>0.1%</td>
<td>0.9%</td>
</tr>
<tr>
<td>Chemicals &amp; Pharma (18.5%)</td>
<td>81.1%</td>
<td>4.9%</td>
<td>4.9%</td>
<td>0.6%</td>
<td>2.6%</td>
<td>5.7%</td>
<td>0.1%</td>
<td>0.1%</td>
</tr>
<tr>
<td>Process Eng. (24.9%)</td>
<td>64.4%</td>
<td>12.3%</td>
<td>17.2%</td>
<td>0.7%</td>
<td>2.2%</td>
<td>2.4%</td>
<td>0.2%</td>
<td>0.6%</td>
</tr>
<tr>
<td>Mechanical Eng. (29.8%)</td>
<td>67.8%</td>
<td>10.5%</td>
<td>17.8%</td>
<td>0.2%</td>
<td>1.1%</td>
<td>1.2%</td>
<td>0.2%</td>
<td>1.2%</td>
</tr>
<tr>
<td>Total</td>
<td>70.6%</td>
<td>8.8%</td>
<td>13.7%</td>
<td>0.8%</td>
<td>2.0%</td>
<td>3.2%</td>
<td>0.2%</td>
<td>0.7%</td>
</tr>
</tbody>
</table>

Number of observations = 8,809. The shares in parenthesis in the first column indicate the share of patents in each technological class (number of observations = 9,014).

Our main concern with survey data was that the information is provided by respondents within the organisations who may not be the best-informed ones. In the case of our survey we were concerned that the inventors, especially if they were employed in large firms or in universities, might not be the most informed respondents on issues like the value of the patents. A manager might know better about these topics. Since we were aware of this problem, we monitored whether the inventors actually knew about the information they were asked to provide during the interviews. In general, our feeling is that they had a pretty good idea about the answers. If anything, they might have overestimated the value of their innovation because of personal factors like pride. This fact, however, may affect the average of our distribution (everyone claims that his innovation is better that it actually is) and not much its shape. We also performed a more rigorous test of the potential bias in the inventors’ answers by using the 587 French patents with responses from both the inventor and the applicant organisation (see Appendix 2).

classes and EPO IPC classes see Hinze et al. (1997). See also the PatVal-EU Report (European Commission, 2005) for the PatVal-EU statistics across the 30 “micro” technological classes.
3 Who are the European inventors?

Who are the European inventors? What is their educational background? What are their motivations to invent? How do these factors explain their research productivity?

The determinants of research productivity over the researchers’ life cycle have been studied in the economic literature as well as in other disciplines. A branch of this literature focus on scientists’ research productivity, and shows that the productivity distribution among scientists is very skewed (see, for example, Allison and Steward, 1974; Cole, 1979; Merton, 1968; Arora, David and Gambardella, 1998). It also shows that vintage and age matter with scientists becoming less productive as they age, with some differences across research fields (see, for example, Levin and Stephan, 1991). This holds after controlling for individual fixed effects. Although information on individual scientists exists in the their scientific institutions, the empirical evidence is often limited because of the cross-sectional nature of the data.

The lack of individual information is more serious for industrial inventors. This explains why the empirical evidence is based on small scale samples, specific industries and firms. A pioneer study on inventors’ productivity is Lotka (1926). Narin and Breitzman (1995) tested the Lotka’s inverse square law of productivity on a sample of inventors in the R&D departments of four companies in the semiconductor industry (see also Ernst et al., 2000 for a study on the inventors of 43 German companies). In general, however, the difficulty to have individual specific information, and to trace the carrier of industrial inventors prevented the research from performing large scale empirical studies that include inventors’ specific characteristics.

The PatVal-EU survey provides a unique opportunity to get access to inventors’ individual information. This is important, as inventors’ characteristics contribute to explain the quantity and quality of research output in Europe, and help design policies for its improvement.

This section provides data on the sex, age, education, motivations to invent and mobility across organisations of the European inventors. Table 3 shows the share of female inventors in the PatVal-EU dataset: there are only 2.8% women in the whole sample. In Chemicals and Pharmaceuticals this share reaches 7.4%, while it drops to 1.1% in Mechanical Engineering. There is some variation of women participation also across countries, with Spain employing 8.2% of female inventors and, at the opposite extreme, Germany with a share of 1.6% (not shown here). These data are consistent with those on women’s participation in S&T reported in the Third European Report on Science and Technology Indicators (European Commission, 2003b). Moreover, our share of female inventors is smaller than the EU-15 share of women participation in all disciplines (29%), in engineering (12%) and in the R&D business sector (European Commission, 2003b), suggesting that women are a big unexploited potential of human capital resources for R&D activities in Europe.

Being an inventor is a middle-age job. The average European inventor is 45 years old, with little variation across technological classes and countries. About 5% of inventors are younger than 30. More than 60% of the inventors are between 30 and 50 years old. About 30% are between 50 and 60, and only 5% are older than 60.
Table 3. Sex, age and education of inventors. Distribution by technological class.

<table>
<thead>
<tr>
<th></th>
<th>% of female inventors</th>
<th>Average age of the inventors*</th>
<th>% of inventors with tertiary education</th>
<th>% of inventors with Ph.D degree</th>
<th>% of inventors who changed employer after the innovation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electrical Engineering</td>
<td>2.0%</td>
<td>43.3</td>
<td>82.3%</td>
<td>19.1%</td>
<td>27.04%</td>
</tr>
<tr>
<td>Instruments</td>
<td>2.7%</td>
<td>44.6</td>
<td>82.0%</td>
<td>33.4%</td>
<td>25.42%</td>
</tr>
<tr>
<td>Chemicals &amp; Pharma</td>
<td>7.4%</td>
<td>44.5</td>
<td>91.8%</td>
<td>59.1%</td>
<td>19.99%</td>
</tr>
<tr>
<td>Process Engineering</td>
<td>2.1%</td>
<td>46.6</td>
<td>72.7%</td>
<td>22.4%</td>
<td>21.20%</td>
</tr>
<tr>
<td>Mechanical Engineering</td>
<td>1.1%</td>
<td>46.2</td>
<td>66.3%</td>
<td>9.3%</td>
<td>21.54%</td>
</tr>
<tr>
<td>Total</td>
<td>2.8%</td>
<td>45.4</td>
<td>76.9%</td>
<td>26.0%</td>
<td>22.47%</td>
</tr>
</tbody>
</table>

The number of observations differs across columns. It ranges between 8861 (for age) and 8963 (for gender).

* Standard deviations are not reported because they are very similar across sectors (9.5 to 9.8)

Note: The question on the mobility of the inventor asked how many times the inventor changed his/her employer/organisation after the one where she/he invented the surveyed patent. The possible answers were: never; 1; 2; 3; more than 3 changes.

If ability is correlated with the level of education (see Griliches, 1970), then the latter might be important for explaining different levels of productivity across individuals and geographical areas. Most of the European inventors (76.9%) have at least a university degree, but the share of inventors with a Ph.D degree is only 26.0%. Both the shares of inventors with university degree and Ph.D vary among technological classes. The best educated inventors are those working in Chemicals and Pharmaceuticals: 91.8% of them have a university degree, and 59.1% have a Ph.D. The least educated ones are in Mechanical Engineering (66.3% come from the University and only 9.3% have a Ph.D). Larger differences in the level of education of the inventors are across countries. Germany shows the largest shares of both tertiary educated inventors (85.3%) and Ph.Ds (35.2%) (not shown in the Table). Spain, France, the Netherlands, and the UK are close to the EU6 share. Italy is lagging behind: the share of inventors with tertiary education is only 56.7% and those with a Ph.D are 3.1%.

Recent contributions point out that there is a positive correlation between the researchers’ productivity and their mobility. They argue that inter-firm and intra-firm mobility serve as a searching mechanism for a “good match” between the potentialities of the employees and the characteristics of the employers for the efficient exploitation of such potentialities (Liu, 1986; Topel and Ward, 1992). Moreover, the mobility of the human capital is a mechanism through which knowledge spillovers take place across organisations (Klepper, 2001; Zucker, Darby and Armstrong, 1998). Interestingly, however, the job mobility of European inventors is limited. The right-end side column in Table 3 shows that most inventors never changed job during their working carrier. The EU6 share of inventors who never moved is 77.5%, with little variation across technological classes. There are differences, however, across countries (not shown in the table). The less mobile inventors are in Spain, where almost 90% of the inventors never changed

5 The hypothesis that these cross-country differences might depend on the technological specialisation of countries is not supported by our data. The share of Italian patents in sectors like Mechanical Engineering or Electrical Engineering where the share of Ph.D is the lowest, is not significantly larger than the share of German or Dutch patents in these same sectors (see the PatVal-EU Report, 2005). This suggests that there might be factors other than the technological specialisation of countries that explain the low educational level of the Italian inventors.
job, followed by Germany (83.1%) and France (82.3%). At the opposite extreme, the UK share of mobile inventors is the largest among the EU6: 34.7% of the English inventors moved at least once from their job, followed by the Netherlands (30.1%). Most of the “mobile” inventors moved only once. The share of EU6 inventors who moved more than once is 7.7%, and the share of inventors who changed employer more than 3 times is 0.8%.

Finally, we investigated the motives of inventors to invent: is it love for research or love for money and carrier that guide their research activity? Table 4 shows six different rewards from patenting that we asked the inventors to rate with a scale from 1 (not important) to 5 (very important). Social and personal rewards (i.e. the fact that the innovation might increase the performance of the organisation where the inventor works, personal satisfaction to show that something is technically possible, and prestige/reputation) are deemed more important than other types of compensation like monetary rewards and career advances, with the ranking being very similar across the EU6.6

Table 4. Inventors’ rewards

<table>
<thead>
<tr>
<th></th>
<th>DE</th>
<th>ES</th>
<th>FR</th>
<th>IT</th>
<th>NL</th>
<th>UK</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average importance of inventors’ rewards</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Monetary rewards</td>
<td>3.0</td>
<td>2.1</td>
<td>3.6</td>
<td>3.0</td>
<td>2.7</td>
<td>3.0</td>
<td>3.1</td>
</tr>
<tr>
<td>Career advances and opportunities for new/better jobs</td>
<td>2.7</td>
<td>2.6</td>
<td>3.3</td>
<td>3.1</td>
<td>2.9</td>
<td>3.3</td>
<td>3.0</td>
</tr>
<tr>
<td>Prestige/reputation</td>
<td>3.7</td>
<td>3.3</td>
<td>2.9</td>
<td>3.1</td>
<td>3.2</td>
<td>3.7</td>
<td>3.4</td>
</tr>
<tr>
<td>Innovations increase the performance of the organisation the inventor works for</td>
<td>4.1</td>
<td>4.1</td>
<td>4.1</td>
<td>4.0</td>
<td>4.1</td>
<td>3.9</td>
<td>4.0</td>
</tr>
<tr>
<td>Satisfaction to show that something is technically possible</td>
<td>4.0</td>
<td>4.0</td>
<td>3.9</td>
<td>3.9</td>
<td>3.9</td>
<td>4.0</td>
<td>3.9</td>
</tr>
<tr>
<td>Benefits in terms of working condition as a reward by the employer</td>
<td>3.0</td>
<td>2.2</td>
<td>1.9</td>
<td>2.8</td>
<td>2.2</td>
<td>2.4</td>
<td>2.6</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Share of inventors who received a monetary compensation</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>% Monetary compensation</td>
<td>61.3%</td>
<td>14.7%</td>
<td>NA*</td>
<td>23.1%</td>
<td>17.5%</td>
<td>28.2%</td>
<td>41.7%</td>
</tr>
<tr>
<td>% Permanent</td>
<td>4.6%</td>
<td>3.2%</td>
<td>NA</td>
<td>5.2%</td>
<td>3.8%</td>
<td>3.2%</td>
<td>4.6%</td>
</tr>
<tr>
<td>% Transitory</td>
<td>56.7%</td>
<td>11.5%</td>
<td>NA</td>
<td>17.9%</td>
<td>13.6%</td>
<td>25.0%</td>
<td>37.1%</td>
</tr>
</tbody>
</table>

The number of observations differs across rows. It ranges between 7360 (for monetary compensation) and 8424 (for satisfaction reward).
The rewards question asked the inventors to rate the importance of the 6 types of rewards for patenting listed in the table. The scale was between 1(not important) to 5 (very important).
Standard deviations are not reported because they are very similar across countries (1.1 to 1.4).
*France is not included for the high number of missing data on this variable.

These results might depend on the fact that the inventors are aware of the “incentive” policies designed by their countries and operated by their organizations, which usually do not contemplate monetary compensation. This is why the inventors’ incentives to innovate might be de facto different from receiving money. In some countries the law regulates the assignment of the property rights between the inventor and the organization. For example, the US Bayh-Dole Act enables the universities to require that their employee disclose their innovations in order to prepare the patent application and to define the distribution of rights between the university and

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6 There are relevant differences in the ranking across macro technological classes.
the government (see, e.g. Mowery et al., 2001.) In Germany, there is a compensation scheme to reward successful inventors: the law establishes that the employers can claim the innovations developed by their employees by “reasonably” compensating them on the basis of the expected value of the innovation, and following the guidelines provided by the German Employees’ Inventions Act signed in 1957. In most European countries, however, there are not national official rules to reward the inventors. Only individual firms design specific incentive policies for their researchers. This is the case, for example, of AT&T that selects a few patents (2 to 5 per year) that receive the “AT&T Strategic Patent Award” for the significant contribution to the company business. Interestingly, our data show that personal and social motivations to innovate are more important than money and carrier also when the inventors actually receive a monetary compensation, as it is shown in the bottom part of Table 4.

Moreover, the share of inventors who actually received a monetary compensation is the largest in Germany (61.3%) because of the German Employees’ Inventions Act. The UK follows with 28.2%. The lowest shares of inventors who receive a monetary compensation are in Italy (23.1%), the Netherlands (17.5%) and Spain (14.7%), confirming that the employers rarely introduce tangible monetary incentives for their researchers. Moreover, when this is the case, the remuneration is transitory in most of the cases.

4 The innovation process and the sources of knowledge spillovers

A growing body of the literature studies the sources of knowledge that firms and scientists use in the innovation process, and the mechanisms through which they get access to such knowledge. One of these mechanisms is the formation of formal and informal networks of researchers and institutions that collaborate to achieve a common research goal. Knowledge spillovers, that are more intense the greater the geographical proximity among individuals and organisations, also play a role in giving access to external knowledge, and in so doing they increase the returns of firms from the investment in R&D (see, for example, Jaffe, 1986; Jaffe et al., 1993). The empirical evidence confirms the clustering of innovative activities and the geographical dimension of knowledge spillovers, and it estimates its effect on firm and regional economic growth (Verspagen, 1997). It also confirms that there are sectoral differences in spatial clustering with skilled and R&D intensive industries that benefit more from co-location and knowledge spillovers (Audretsch and Feldman, 1996; Breschi, 1999).

In order to assess whether different patent holders rely on each other knowledge bases, and to measure the geographical dimension of such exchange, most contributions use patent citations. This is the case of Jaffe, Trajanberg and Henderson (1993) who analysed the spillovers across geographically close inventors. Similar studies have been carried out for Europe (Verspagen, 1997; Verspagen and De Loo, 1999; Verspagen and Schoenmakers, 2004). For the US and Japan, Branstetter (2001) suggest that knowledge spillovers are primarily intra-national in scope. Although interesting, the validity these results depend on the goodness of patent citations to measure knowledge flows. As mentioned in Section 1 there is a debate on this issue. Jaffe,

Trajtenberg and Fogarty (2000) confirm that patent citations reflect the existence of knowledge spillovers as perceived by the participants, albeit with substantial noise. Also Jaffe, Fogarty and Banks (1998) find that two-thirds of citations to patents of NASA-Lewis' Electro-Physics Branch were evaluated as involving spillovers. By contrast, Alcacer and Gittelman (2004) show that an important fraction of patent citations are included by the examiners, rather than by the inventors, leading to an unknown noise in the use of patent citations for studying the extent and direction of knowledge flows. Moreover, these contributions do not explain the sources of knowledge spillovers, and they typically describe the spillovers as merely “in the air”. Only some recent studies show that they do not occur unintentionally, and that the rise of externalities depends on specific complementary actions of the economic agents (Zucker et al., 1998a, 1998b, Breschi and Lissoni, 2001).

This Section uses different indicators drawn from the PatVal-EU survey to shed some light on these issues. It looks at the innovation process, and it examines the importance of R&D collaborations among individuals and organisations, the role of geographical proximity to establish the collaborations, and the use of different sources of knowledge in the innovation process.

4.1 The role of collaborations in the production of innovations

The patent document lists the names of the inventors that take in the development of the innovation. Only one third of the overall number of PatVal-EU patents is developed by “individual” inventors, suggesting that an innovation is often the result of a research collaboration among individuals. The patent document, however, does not provide good information on whether the collaborations are among inventors belonging to the same organisation, or to different organisations, and the type of collaboration they establish.

Co-applied patents (i.e. patents applied at the patent office by multiple organizations) are the only information provided by the patent document on the extent to which the inventors involved in the production of a patent are affiliated to different organisations. This information is used in the literature to indicate the existence of R&D collaborations among organisations, and to proxy for the companies’ sharing of intellectual property rights (Hagedoorn, 2003). However, as Hagedoorn (2003) points out, firms consider this type of partnering as sub-optimal due to the legal complexities to manage intellectual properties across firms’ boundaries and international patent jurisdictions. He also shows that co-patenting is more frequent in sectors like chemicals and pharmaceuticals where patent protection is stronger and the scope for legal controversies is limited. Therefore, the data on co-patenting may be bias towards the technologies where patent protection is more effective, and they may underestimate the extent to which organisations collaborate in R&D. Balconi et al. (2004) show that there are collaborations in patenting activities that do not emerge in the patent document.

The PatVal-EU data shed light on this issue. Apart from the information on co-applied patents available from the patent document, it provides information on the affiliation of the inventors involved in the production of multiple inventors’ patents. This makes it possible to bring to light the existence of external collaborations that were “invisible” in the patent document. Moreover,
for each patent the respondents indicated if the patent was developed in collaboration with other partners and if the collaboration was formal or informal.

The left-end column in Table 5 shows that the EU6 share of co-applied patents in our sample is 3.6%, and it ranges between 5.4% for France and 2.8% for the UK. It is a little bit higher when we include in the co-applicants also companies belonging to the same corporate group. If we compare these data with the information provided directly by the inventors on the extent to which they collaborate with researchers from other institutions to develop the innovation, it clearly shows that most of the collaborations are internal to the organisation. However, the share of patents developed in collaboration with people external to the organisation is much larger than the share of co-applied patents. It is 15.0% of the EU6 patents are produced by teams of inventors affiliated to different organisations.

This share is the largest in the UK, and the smallest in Spain and Italy. It is small also for the inventors employed in the private companies, and in particular by the large industrial companies (about 12% on the total number of patents, not shown here), suggesting that these firms tend to internalise the innovation process within their boundaries, and coordinate internally the production of innovation and the transfer of knowledge among inventors.

Table 5 also shows the share of patents produced by the collaboration between the inventor’s organisation and other partner organisations. There are more than 20% of collaborative patents at the EU6 level, with the Netherlands reaching 34.5%, and Germany falling to 13.3%. Moreover, when different firms and institutions take part in a research project leading to a patent, the partners normally establish a formal collaboration (74.6%), meaning by this a well-defined contract among the parties to collaborate over an R&D project. The remaining one fourth of the collaborations are managed on informal basis. Interestingly, the share of collaborative patents is similar to that of patents developed with external inventors, suggesting that collaborations, also those at the micro-inventor level, take place through formal agreements, and only a minor
fraction might be in the form of the knowledge spillovers among inventors and institutions that are not mediated by any apparent market mechanism.\(^8\)

Finally, by comparing the share of co-applied patents with the share of “collaborative” patents among researchers belonging to different institutions, it shows that many collaborations (even the formal ones) do not result in joint patent application, probably because of strategic reasons concerning the attribution of IPRs. Again, this confirms that the use of patent data alone to derive indicators on research collaborations among inventors and institutions underestimates the real extent of collaboration in the development of a patent.

4.2 Geographical proximity and the exchange of knowledge among inventors

Another mechanism for the exchange of knowledge among inventors is the geographical proximity. We compare the importance of being located close to each other to the role of “organisational proximity” (i.e. affiliation to the same organisation) in order to collaborate on a patent. The PatVal-EU survey asked the inventors to use a scale from 1 to 5 to rate the importance of 4 different types of interaction while developing the innovation: (1) interaction with people internal to the inventor’s organization, and geographically close (i.e. less than one hour to reach them physically); (2) interaction with people internal to the inventor’s organization, and geographically distant (i.e. more than one hour to reach them physically); (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.

Figure 1 shows the average importance of the four forms of interaction. “Organisational proximity” seems to be the most effective means of coordination: the interaction with other members of the same organization is 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 equally the importance of the interaction with people from the same and other organisations (1.3).

\(^8\) Private companies, and particular large firms, produce the lowest share of collaborative patents. By contrast, research institutions and Universities set up the largest share of patents involving external co-inventors, the largest share of collaborative patents, and the largest share of co-applied patents.
Figure 1. Importance of geographical proximity and “organisational” proximity of inventors. Scale: 1 (not important) to 5 (very important)

3.0
1.3
0.9
1.3

Number of observations = 8180.

Surprisingly, the interaction with researchers affiliated to different organizations that are geographically close is the least important form of collaboration in all the EU6 countries, suggesting that geographical proximity is not crucial for developing research linkages among individuals that are affiliated to different institutions. This is puzzling, especially given the number of contributions in the literature that emphasise the importance of geographical proximity for fostering collaborations and reducing the costs of transferring knowledge among independent parties. Since the literature suggests that geographical localised spillovers are more important in technological fields where innovation is centered on smaller technology-intensive companies that are organised in cluster-like forms we checked whether geographical proximity ranked differently according to the technological class in which the patent was invented. We therefore computed the average importance of the four types of interaction for the 5 macro and 30 micro technological classes (ISI-INPI-OST classification system). The ranking does not change as compared to the above in all the technological classes, with the interaction among geographically close and external researchers being the least important form of interaction (See European Commission, Tender Report, 2005 for the statistics).

4.3 The sources of knowledge in the innovation process

The last issue we analyse about the innovation process concerns the sources of knowledge used to develop the innovations. The sources of knowledge we asked the inventors to rate with a scale from 1 (not important) to 5 (very important) are: the firm’s competitors, the suppliers, the customers, other patents developed before the patent in the survey, the scientific literature, the participation in conferences and workshops, the knowledge developed in university and non-university laboratories. Figure 2 shows the average importance of the six sources of knowledge as rated by the inventors.
The firm’s customers are the most important source of innovation, followed by the knowledge supplied by the patent literature and the scientific literature. The fact that the patent literature is considered an important source of knowledge to develop the innovation confirms the goodness of patents and patent indicators in the innovation literature. If patents are an important source of knowledge to develop other innovations, it also makes sense to use patent citations to measure the importance of the patents or the extent of knowledge spillovers from the cited to the citing document. Other sources of knowledge are important as well. This is the case, for example, of the firm’s competitors that rank fourth in the list, before the participation in conferences and workshops. The contacts with the firm’s suppliers come sixth. Surprisingly, University and non-university research laboratories are the least used source of knowledge in the innovation process.

5 The destiny of European innovations: the use and value of EPO patents

5.1 The use of patents

What is the use that firms make of their patents? Why are some patents exploited commercially, while others are licensed out to other firms, and other, still, are left unused? These are relevant issues, as the ability to translate new technologies into economically valuable goods or services is crucial for the competitiveness of firms, regions, and countries. This section uses the PatVal-EU data to answer some of these questions.

It is well known that the path between innovation and the commercialisation of a new product or a new technology can be long and costly. Many patents are never exploited commercially, and only few innovations yield economic returns. The decision of non-using a patent might depend
on the intrinsic features of the innovations, or on other factors. For example, the owner might not have the needed downstream assets to exploit it, which is typically the case of small firms, individual inventors, and scientific institutions. At the same time, the licensing of patent rights and the development of markets for technology help exploit the potential returns from the innovations (Arora, Fosfuri and Gambardella, 2001; Rivette and Kline, 2000).

Also large firms might leave some of their patents unused (i.e. “sleeping patents”) (Palomeras, 2003; Rivette and Kline, 2000). This happens when the patents are applied for strategic reasons such as to block the firm’s competitors, to improve the bargaining power of the company in cross-licensing agreements, or to avoid being blocked by the firm’s competitors (Hall and Ziedonis, 2001; Ziedonis, 2004). The literature emphasises the policy implications of the “non-use” decision (Scotchmer, 1991; Mazzoleni and Nelson, 1998) and it argues that the strength and the effectiveness of patent protection can increase the propensity to patent and, at the same time, it reduces the actual use of the patents. Moreover, the social cost of non using a patent is higher when it has a broad scope, due to the fact that the applicants do not exploit these patents commercially, and they also prevent the potential use of the innovations by others (see also Merges and Nelson, 1990).^9^ These issues need further empirical investigation. For example, the literature on licensing focuses on sectors in which licensing is more frequent like computer, semiconductors, and chemicals (See Grindley and Teece, 1997, and Hall and Ziedonis, 2001, for the semiconductor industry; Arora, Fosfur and Gambardella, 2001, Cesaroni, 2003, Grindley and Nickerson, 1996, for the chemical industry; Kollmer and Dowling, 2004, for the biopharmaceutical industry), or it uses aggregate cross-section analysis (Anand and Khanna, 2000; Cohen et al., 2000, Arora and Cuccagnoli, 2005). In general, information on the use, non-use and actual “destiny” of the patents is not available, especially for Europe and for cross-country and cross-sector studies.

The PatVal-EU survey provides a unique opportunity to explore these issues. We asked the PatVal-EU inventors whether their patents were used for commercial or industrial purposes, and if they were licensed out. We also asked them to rate the importance of different motivations for patenting (on a scale from 1 to 5), including licensing, cross-licensing and strategic reasons like blocking competitors.

From the responses of inventors to these questions we defined six possible uses of patents: 1) **Internal use**: the patent is exploited internally for commercial or industrial purposes. It can be used in a production process or it can be incorporated in product; 2) **Licensing**: the patent is not used internally by the applicant, but it is licensed out to another party; 3) **Cross-licensing**: the patent is licensed to another party in exchange for another patented innovation; 4) **Licensing & use**: the patent is both licensed to another party and used internally by the applicant organisation; 5) **Blocking competitors**: the patent is not used (neither internally, nor for licensing). It is held unused in order to block competitors; 6) **Sleeping patents**: the patent is “sleeping” in the sense that it is not employed in any of the uses described above.

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^9^ Nagaoka (2003) show the data on the use of patents by large Japanese firms. Cohen et. al (2000) show the motivations for patenting by large US companies with formal R&D departments. They argue that, apart from the mere protection of the innovations, licensing, cross-licensing and other strategic reasons like ‘blocking patents’ are also important motivations to patent.
Table 6 shows that at the overall EU6 level, half of the patents (50.5%) are exploited by the applicant organisation for industrial and commercial purposes. About 36% of the patents are not used. Specifically, 18.7% are applied for strategic reasons and 17.4% are “sleeping” patents.\(^{10}\) Fifteen percent of the patents are exchanged in the market for technologies: 6.4% are licensed, 4.0% are both licensed and internally used, and 3.0% are used in cross-licensing agreements.

The use of patents differs across the five technological classes. More than half of Process Engineering and Mechanical Engineering patents are used for internal purposes (54.6% and 56.5% respectively), while only 37.9% of Chemical and Pharmaceutical patents are used internally. About 50% of the patents in Chemicals and Pharmaceuticals are not used: 28.2% are “blocking” patents, and 22.3% are “sleeping” patents. Consistently with the existing evidence on licensing activities (Anand and Khanna, 2000) Chemical and Pharmaceutical patents are licensed frequently (6.4%), while Licensing & use and Cross-licensing are used less than the average (2.5% and 2.6% respectively). The share of cross-licensing is above the average in Electrical Engineering and Instruments (6.1% and 5.0%), which confirms 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 under-estimated the importance of patenting in Process Engineering and Mechanical Engineering, in which the share of unused patents in these technologies is the lowest among the five technological classes.

| Table 6. Patent use. Distribution by technological class |
|----------------------------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|
| | Internal use | Licensing | Cross-licensing | Licensing & Use | Blocking Competitors (unused) | Sleeping Patents (unused) | Total |
| Electrical Engineering | 49.2% | 3.9% | 6.1% | 3.6% | 18.3% | 18.9% | 100.0% |
| Instruments | 47.5% | 9.1% | 4.9% | 4.3% | 14.4% | 19.8% | 100.0% |
| Chemicals & Pharma | 37.9% | 6.5% | 2.6% | 2.5% | 28.2% | 22.3% | 100.0% |
| Process Engineering | 54.6% | 7.4% | 2.0% | 4.9% | 15.4% | 15.7% | 100.0% |
| Mechanical Engineering | 56.5% | 5.8% | 1.8% | 4.2% | 17.4% | 14.3% | 100.0% |
| Total | 50.5% | 6.4% | 3.0% | 4.0% | 18.7% | 17.4% | 100.0% |

Number of observations = 7,711

Table 7 provides another interesting piece of information: 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. They trade 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 “sleeping” patents. Hall and Ziedonis (2001) study the semiconductor industry, but they do not find conclusive evidence on this issue. Table 7 also shows that medium-sized firms use internally 65.6%. This

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\(^{10}\) Since we over-sampled important patents, the share of unused patents in the population is probably higher than the share in Table 6.
share is 55.8% for the small firms. Consistently with our expectations that the cost of patenting is relatively larger for small firms, they tend to use more intensively their patents, and to appropriate the returns from their innovation in the market for technology. Small firms leave unused only 18% of their patents (for “blocking” and “sleeping” reasons), and license out about 26% of the patents. As expected, public or private research organizations and university license a large fraction of their technologies and do not use them internally (see, Mowery et al., 2001 for some evidence on university licensing in the US).

Table 7. Patent use. Distribution by type of inventors’ employer

<table>
<thead>
<tr>
<th>Type of Inventors’ Employer</th>
<th>Internal use</th>
<th>Licensing</th>
<th>Cross-licensing</th>
<th>Licensing &amp; Use</th>
<th>Blocking Competitors</th>
<th>Sleeping Patents</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Large companies</td>
<td>50.0%</td>
<td>3.0%</td>
<td>0.0%</td>
<td>3.2%</td>
<td>21.7%</td>
<td>19.1%</td>
<td>100.0%</td>
</tr>
<tr>
<td>Medium sized companies</td>
<td>65.6%</td>
<td>5.4%</td>
<td>1.2%</td>
<td>3.6%</td>
<td>13.9%</td>
<td>10.3%</td>
<td>100.0%</td>
</tr>
<tr>
<td>Small companies</td>
<td>55.8%</td>
<td>15.0%</td>
<td>3.9%</td>
<td>6.9%</td>
<td>9.6%</td>
<td>8.8%</td>
<td>100.0%</td>
</tr>
<tr>
<td>Private Research Institutions</td>
<td>16.7%</td>
<td>35.4%</td>
<td>0.0%</td>
<td>6.2%</td>
<td>18.8%</td>
<td>22.9%</td>
<td>100.0%</td>
</tr>
<tr>
<td>Public Research Institutions</td>
<td>21.7%</td>
<td>23.2%</td>
<td>4.3%</td>
<td>5.8%</td>
<td>10.9%</td>
<td>34.1%</td>
<td>100.0%</td>
</tr>
<tr>
<td>Universities</td>
<td>26.2%</td>
<td>22.5%</td>
<td>5.0%</td>
<td>5.0%</td>
<td>13.8%</td>
<td>27.5%</td>
<td>100.0%</td>
</tr>
<tr>
<td>Other Governm. Institutions</td>
<td>41.7%</td>
<td>16.7%</td>
<td>0.0%</td>
<td>8.3%</td>
<td>8.3%</td>
<td>25.0%</td>
<td>100.0%</td>
</tr>
<tr>
<td>Other</td>
<td>34.0%</td>
<td>17.0%</td>
<td>4.3%</td>
<td>8.5%</td>
<td>12.8%</td>
<td>23.4%</td>
<td>100.0%</td>
</tr>
<tr>
<td>Total</td>
<td>50.5%</td>
<td>6.2%</td>
<td>3.1%</td>
<td>3.9%</td>
<td>18.8%</td>
<td>17.5%</td>
<td>100.0%</td>
</tr>
</tbody>
</table>

Number of observations = 7,556

5.2 Entrepreneurship and patents

A patent can also be used to set up a new firm that exploits it economically. Many start-ups in industries like biotechnology, semiconductors, instruments and chemicals use their intellectual property as a means for obtaining financing and corporate partners that are critical for the their success and growth. Moreover, the existence of patent rights encourages the formation of firms that operate in the upstream innovation sector, and the development of the markets for technology (Arora and Merges, 2004). If firms do not have the resources and the capabilities needed to exploit the innovation economically, they might decide not to produce it in the first place. The existence of intellectual property rights enables them to sell the property rights on the innovation to other firms that own the downstream complementary assets.

Recent contributions study these issues, mostly for the US. They analyse the formation of spin-offs that use patents licensed from universities (Shane and Kharuna, 2003), large firms (Klepper, 2001), and venture capitalists (Gompers, Lerner, and Sharfstein, 2004). Cross-section empirical evidence based on large data samples is limited. The evidence for Europe is completely missing.

The PatVal-EU survey asked the inventors whether his patent was exploited commercially by starting a new company. Figure 3 shows the share of patents in the PatVal-EU sample used to start-up a new firm by country and technological class. At the overall EU6 level, 5.1% of patents give rise to a new firm. This share is the largest in the UK (9.7%) and in Spain (9.3%). It is the smallest in Germany (2.7 %) and in France (1.6%). It is also worth noticing that in the UK the share of licensed patents and new firm formation is higher than the EU6 average, together with the share of tertiary educated and PhD inventors, and with the propensity to patent by universities and research institutions in general.
In terms of technological class, the share of new firms is the largest in Instruments (7.5%), followed by Process Engineering (5.6%) and Mechanical Engineering (5.4%). In Chemicals & Pharmaceuticals only 3.1% of the patents are used for creating a new firm. One of the more prolific “micro” technological classes is Medical Technology with 10.5% of patents that gave rise to a new firm.

5.3 The economic value of patents.

The monetary value of patents is typically estimated in the literature by using indirect measures. 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 indicators are also employed to construct composite indicators of the quality of patents (Lanjouw and Schankerman, 2004). Only a few studies use survey-based information on the economic value of patents in specific countries (see, for German and US patents, Harhoff et al., 1999a, 1999b, 2003; Scherer and Harhoff, 2000).

The PatVal-EU survey provides new data on the monetary value of patents. 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.\textsuperscript{11}

Figure 4 shows the distribution of the value of the PatVal-EU patents by technological class. We constructed 10 value classes, ranging from patents 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 (Harhoff \textit{et al.} 1999a, 2003; 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. The largest share of patents falls in the left-end of the distribution. About 68\% of all our patents produce less than 1 million Euros, and about 8 \% have a value lower than 30 thousand Euros.\textsuperscript{12}

\begin{figure}
\centering
\includegraphics[width=\textwidth]{figure4.png}
\caption{The value of European patents across macro technological classes}
\end{figure}

Note: Number of observation = 7,752.

Technology specific characteristics make the value distribution different across technological classes. For example, innovations that are worth more than 10 million Euros are more frequent in Chemicals and Pharmaceuticals (11.7\%) compared to the overall sample (7.2\%), while it is rare

\textsuperscript{11} 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. Appendix 2 of this paper describes the test we performed on this potential bias.

\textsuperscript{12} The PatVal-EU sample overweights opposed patents and patents with at least one citation. This makes our distribution more skewed to the right than the distribution of actual population of patents. Moreover, the availability of the on the patents’ monetary value offers the opportunity to explore the right-end tail of the patent value distribution, which cannot be observed by using other indicators like patent citations (which would be 0 for a large share of low value patents).
in Instruments (5.6%). Symmetrically, 58.0% of the Chemical and Pharmaceutical patents are in the left-end tail of the distribution where patents generate less than 1 million Euros, while Electrical Engineering, Instruments, Process Engineering and Mechanical Engineering have a share of about 70% of patents with a value lower than 1 million Euros.

Compared to previous surveys, PatVal-EU survey provides the information on the monetary value for a large sample of patents produced in different (micro and macro) technological areas, in different European countries, and in a large variety of public and private organisations. By checking for the correlation between our monetary value and the indirect indicators that the literature typically uses, we can validate the latter as proxies for the economic importance of the patents when the information on economic value is missing. Moreover, by using the survey data together with other data drawn from external sources, we can estimate the contribution of different determinants to the value of the patents.\(^\text{13}\)

6 Conclusions

The investment in the production of new ideas, new knowledge, and new technologies is the engine of firms and countries’ competitiveness and economic growth. This paper presented the micro-level foundations of these processes by providing new evidence on the characteristics of the inventors, the innovation process and the innovations it produces in six European countries.

The availability of direct and detailed information is a major improvement for understanding important issues in the economics of innovation and technical change. Indeed, apart from a few patent surveys with limited European coverage and mostly biased towards large companies, the managerial and economic literature has always suffered from the limited availability of detailed and direct data on the characteristics of the innovation process and the economic value of its output. The PatVal-EU survey was precisely designed to close this gap. Compared to previous surveys on patents, the PatVal-EU survey has a broader coverage in terms of European countries, and types and size of the applicant organisations.

The first step of the paper was to describe the characteristics of the European inventors. Our data confirm the extremely limited participation of women in the innovation activities in Europe: 2.8% on the total PatVal-EU sample. In terms of educational background, about three fourths of the European inventors in the PatVal-EU dataset have a university degree. Only one fourth of the inventors have a Ph.D, with Italy lagging behind in both categories. Moreover, the European inventors are little mobile across jobs: more than three fourths of the PatVal-EU inventors never moved from their job. The UK is the country with the largest share (almost 40%) of inventors who changed job at least once during their carrier.

\(^{13}\) From the The PatVal-EU data we derived the distribution of the patent value by type of inventors’ employer (See European Commission, Tender Report, 2005). Our survey also provides information on the costs for producing the innovations, both in monetary terms and in the amount of time devoted to the process that led to the patent. These data show that there is a large share of short research projects, suggesting that many “small” innovations are also patented. This is consistent with the share of “intertwined patents” (44%) in our sample (i.e. patents that crucially depend on each other technically or in terms of their value).
A novel piece of information produced by the PatVal-EU survey concerns the motivations of the inventors to invent. Interestingly, the inventors consider monetary rewards and other rewards like career advances and benefits less important than personal and social rewards, like personal satisfaction, prestige, reputation, and the contribution to the performance of the organization.

We then moved to the innovation process. Only one third of the patents is developed by “individual” inventors, suggesting that inventions are a team activity. However, the vast majority of these co-inventors belong to the same organisation: only 15.0% of the EU6 patents are produces by teams of inventors affiliated to different organisations. At the organisational level, 20% of patents are developed through the collaboration with other institutions. Seventy-five percent of these collaborations are formalised through specific contracts. Only one fourth of the collaborations are managed on an informal basis. Finally, by comparing the share of co-applied patents with the share of collaborative patents, it shows that a large fraction of the collaborations does not result in joint patent applications, suggesting that the use of patent data alone to derive indicators on research collaborations among inventors and institutions in the innovation process strongly underestimate the actual extent of collaboration in the development of a patent.

As far as the sources of knowledge used in the innovation process are concerned, the most important one is the interaction with the customers, followed by the knowledge supplied by the patent literature and the scientific literature. The interaction with the firm’s competitors, the participation in conferences and workshops and the contacts with the suppliers rank afterwards. Surprisingly, university and non-university research laboratories are at the bottom of the list. This is so for the EU6 as a whole, with very little variation among countries. Interestingly, while “organisational proximity” among inventors matters for fostering interaction among them in the research activity, geographical proximity per se does not seem to influence the probability of collaboration among researchers affiliated to independent organisations.

The survey produced information also about the use and non-use of patents. These are important decisions, as unused patents are socially undesirable because both the owner of the patent right does not exploit it economically, and other potential users are prevented from doing so. An understanding of the factors that influence the decision to use a patent would help design policies for the efficient and extensive exploitation of the innovations. Finally, we presented evidence on the distribution of the monetary value of the PatVal-EU innovations, and we confirm that the distribution of patent values is skewed, and only few patents yield large returns.

We conclude by saying that this paper is the first of a series of contributions based on the PatVal-EU survey that will explore specific aspects of the innovation process, the determinants of its outcomes, and the policy implications for the intellectual property system and more generally for improving the innovative performance of firms and regions. Future work will also employ complementary patent data like backward and forward citations, oppositions, claims, etc. It will also use additional data at the inventors’ level (i.e. the patents they developed over their life cycle), at the company level (like their size, sector and other characteristics) and at the geographical level. Apart from the richness of information they provide for the purpose of analysing specific issues, the use of data external to the survey will also control for the fact that survey data are all internally generated.
Annex 1. The PatVal-EU Survey

The PatVal-EU dataset is based on a survey directed to 27,531 EPO patents with priority date 1993-1997. At the time of the innovation the inventors of these patents were located in the six European countries that participate in the project: France, Germany, Italy, the Netherlands, Spain, and the UK. This appendix describes the methodology adopted in the survey.

The questionnaire focussed on the topics described in Section 2, and it was articulated in six sections: A) Inventor’s Personal Information; B) Inventor’s Education; C) Inventor’s Employment and Mobility; D) The Innovation Process; E) Inventor’s Rewards; F) The Value of the Patent.

The sampling procedure. At the time of the survey our six countries covered 42.2% of the total EPO patents by country of first inventor, and 88.0% of the EPO patents with country of first inventor being one of the EU-15 (source: EPO EPASYS database). Patents were assigned to countries according to the location of the first inventor in the inventors’ list. The share of questionnaires submitted to the inventors in each country depended on the country share of patents in the whole population: Germany 49.7%, France 19.5%, the UK 15.0%, Italy 8.5%, the Netherlands 6.2% and Spain 1.07%. We only decided to under-sample the share of German and French patents, and to over-sample the patents invented in the other countries in order to have sufficiently large samples for all countries. Our goal was to reach about 10,000 questionnaires responded by the inventors. We therefore set the following target responses by country: 3,500 for Germany, 1,750 for France, 1,750 for the UK, 1,250 for Italy, 1,250 for the Netherlands, and 500 for Spain. The response rate obtained in the pilot surveys helped decide the number of questionnaires to send to the inventors in each country in order to obtain returns close to the target. To improve the response rate, the EPO and the European Commission provided us with a cover letter for the questionnaire.

As for the period we decided to survey, our population is composed of all EPO granted patents with priority date between 1993 and 1997. This is because, if we sampled very “old” patents, it would have been difficult to track the inventors or to find someone who had memory about the innovation process. By contrast, very “recent” patents might not carry enough information about their value and use.

In the sampling procedure we also considered the fact that the distribution of patent values is highly skewed. We therefore decided to over-sample the “important” patents, meaning by them those patents that were opposed or that received at least one citation, in order to have enough information on the upper tail of the distribution of the patent value. In the end we selected a stratified sample of 27,531 EPO patents that included all the opposed or cited patents in the 1993-1997 patent population, and a random sample of the not-cited and not-opposed patents. The over-sampling procedure produced about 15% additional observations for the “important patents” at the aggregate EU6 level (43.2%) compared to the initial population (which is about 28%).

14 The over-sampling implies that we have to be cautious when making inferences about the population of patents from our sample. Any factor that is positively correlated with the importance of the patent will be over-represented.
Finally, in defining the sample, we had to deal with the fact that some inventors invented more than one EPO patent. If they had to fill out multiple questionnaires, they could decide to drop them all, producing a potential bias against the more prolific inventors. To avoid this problem, we decided to send a maximum of five questionnaires per inventor even if he/she was listed in more than five patents in our sample (very few cases). We also asked the multiple patents’ inventors to fill out the complete questionnaire for only one patent, and to skip Section A (and possibly B and C) in the other patents. Whenever possible, we asked the co-inventors to fill out some of these patents, and we exerted a special effort to convince the multiple patents’ inventors to respond to the survey.

**Searching for the inventors.** A critical phase in the PatVal-EU survey was to search for the recent addresses and telephone numbers of the inventors listed in the patents. We faced two problems. First, the patent document does not include the inventors’ telephone number, which we needed in order to check their address and to contact them for the telephone interviews. Second, many addresses of the “mobile” inventors at the time of the survey had changed with respect to those listed in the patent in 1993-1997. To solve these problems we designed a common set of rules to search for the inventors’ addresses and telephone numbers in the six countries. We started by looking for the address of the first inventor as listed in the patent in the Yellow and White Pages directories of telephone customers in each country, and we obtained about 64% of “exact matches” (i.e. the name-surname and address listed in the patent was the same as that in the White Pages).\textsuperscript{15} These inventors could easily be approached. Similarly, it was not difficult to contact the inventors whose address reported in the patent was the address of the organisation in which they worked. We contacted the company and we asked to interview the inventor. However, some inventors moved from their job and from their town, which made it hard to find them. The Pilot tests below describe the strategy we adopted to find them anyway.

**Pilot surveys.** We performed three pilot tests before running the full-scale survey. The goals of the Pilot tests were to choose the best method for submitting the questionnaire in each country (mail, telephone, web) and to check if the respondents understood the questions clearly. In the last Pilot test we also reproduced the conditions under which the full-scale survey was going to be performed in order to single out potential problems.

During the Pilot tests we also codified a common procedure to retrieve the inventors whose address in the White or Yellow Pages did not match with that in the patent document. Indeed, to avoid sample biases, we wanted our sample to include also the inventors who moved after the patent application, and that we did not find in the telephone directory (or that we found with a different address). In order to look for a more recent address of these inventors, we started by searching for other EPO patents they might have invented after 1997. This procedure alone,

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\textsuperscript{15} In the UK the “exact match” rate was only 18%, compared to 65% in France, 86% in Germany, 62% in Italy, 66% in the Netherlands and 89% in Spain. This is because people in the UK are asked whether they want to be listed in the phone directory, while in the other countries they are listed without asking for permission.
however, posed the problem of a potential bias towards the mobile and productive inventors who produced other EPO patents later on.\textsuperscript{16}

We therefore decided to search for two types of “non-exact matches”: inventors \textit{with} and \textit{without} EPO patents after 1997. In the former case, if the address in the later patent matched the one we found in the phone directory, we contacted the inventor for submitting the questionnaire. The problem was for the inventors who did not have other EPO patents. To trace them, we performed the following search: 1) We checked whether the same name-surname was in the city at a different address. In this case, we called the person. If there were up to 2-3 individuals with the same name-surname, we called them all to find out who was our inventor; 2) We searched for the same name-surname in the wider regional area and at the national level. Again, we called the person to find out whether he was the inventor (up to 2-3 people); 3) We used the address of the second or third inventors (if there were any) in our 1993-1997 survey sample of patents, and we asked them information about the first inventor (including his address). Only if we could not find the first inventor, we asked the second or third inventor to respond to the questionnaire; 4) We finally searched for the inventors in the US patent data, and we surfed on the web for useful information. To harmonise the procedure we issued a “Guideline to search for the inventors” that was distributed to the team members.

\textbf{The full-scale survey.} In order to maximize the response rate, each team decided the methodology to apply to his country during the full-scale survey, and all the teams employed a “recall strategy”. For the details about the specific country strategy for the interviews see the PatVal-EU Report (2005) and the annexed questionnaire. The full-scale survey started in May 2003. The last country to finish the interviews was France in April 2004.\textsuperscript{17}

\textbf{The final dataset.} Section 2 of this paper describes the composition of the final dataset. We add here that our final dataset includes about 7% responses from inventors whose exact address only matched a later EPO patent (after 1997) and 5% inventors without a later EPO patent, whose address was found with the procedure discussed under Pilot 1.\textsuperscript{18} Because the exact matches were 64\%, our full-scale dataset under-represents the 36\% non-exact matches. Also, we have no way to figure out whether the proportions between inventors with and without later EPO patents are really 7 over 5. We can only say that we have to be careful about this potential bias in our data. However, the high rate of exact matches (64\% on average, but even above 80\% for Germany or Spain, and about two-thirds for France, Italy and the Netherlands) suggests that in Europe the mobility of inventors is not pronounced, and that therefore, the extent of this potential bias may not be dramatic. This is confirmed by the data on inventors’ mobility in Section 3.

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\textsuperscript{16} In the UK we had the additional problem that the phone-books does not report the full fist name of the customers, making Steps 1, 2, and in part 3 very hard to perform, with a large number of telephone calls to find the person. This also explains the large number of questionnaires that the UK had to send out to reach the target responses.

\textsuperscript{17} In each country a professional poll-company conducted one or more steps of the survey. Only the Dutch team performed all the tasks internally, while in France the survey was conducted by the Ministère de la jeunesse, de l’éducation nationale et de la recherche, and it started in September 2003.

\textsuperscript{18} There are minimal differences in these two percentages across our six countries.
Annex 2. Check for the goodness of the responses: the French test

Our concern with the PatVal-EU data is the bias that the inventors might introduce if they are not the best informed persons in the organisation on issues like the value of the patents. A manager could be a more suitable person to ask, especially in universities and in large firms. Yet, we did not have access to good information about the applicant organisations, and who to contact to get better information than that provided by the inventors. By contrast, for the inventors we had an address in the patent document from which to start locating them. In addition, the inventor is a well-defined “type” of individual to look for, and definitely one who knows about the patent. By contrast, a “knowledgeable” person for our patents is a more blurred type: he could be the manager of a patent department, or simply the boss of the inventor, or the technology licensing manager in a university. If we sent the questionnaire to the applicant organisations without checking who was going to answer, this procedure would not have produced better estimates and response rates than asking the inventors, who, at least, were there when the patent was invented. We therefore concluded that asking the inventor was the best option that we had to pick systematically, at the scale we chose to conduct our survey, a person who had, on average, a reasonably good knowledge about the patent.

However, to check for the potential bias in the inventors’ responses we performed a rigorous test. The opportunity arose from the French survey that was conducted by the Ministère de la jeunesse, de l’éducation nationale et de la recherche in Paris. The Statistical Department of the Ministry had extensive databases and information about the applicant organisations that made it easier to contact them. As a result, the questions about the costs of the research, the source of funding, the use and the value of the patents were asked to the patent applicant. Only the question about the monetary value of the individual patent was asked to both the inventors and the companies. All the other questions were asked only to the inventors. We used the patent value question for our test. For this question the French questionnaire had 354 patents with valid answers by both the inventor and the applicant organisation.

First of all, we found out that the distributions of the value classes given by the inventors and by the managers overlap to a great extent. Moreover, a two-tail t-test did not reject the hypothesis that the two means are different for a p-value smaller than 10%. Pride or other factors may induce the inventors to boost the results of their work, and hence to overestimate the value of their patents. If so, it is reasonable to employ a one tail t-test of the null hypothesis of no difference between the two means against the alternative that the mean response of the inventors is higher than that of the managers. In this case the null hypothesis is rejected at p < 5%, suggesting that the inventors overestimate the value of their patents compared to the managers. However, such an overestimation is small. The PatVal-EU Report (2005) describes the details of these and other tests that we performed.

We also compared the different responses between inventors and managers in the small and large firms. As noted earlier, the inventors in the large companies may be less informed about the

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19 In France 587 patents were responded by both the inventor and the applicant organisation. However, for 233 of these patents there was no response to the value question by either the inventor, the applicant or both, leading to 354 patents with valid answers from both.
value of their patents because of the greater organizational distance and the more intensive specialization of tasks. As a result, the gap in response should be wider in these firms. Among our 354 French patents we distinguished between the patents applied for by the large firms (more than 250 employees), the small-medium firms (less than 250 employees), and the universities and other research organisations. We found that there is a slight overestimate of the inventor’s assessment of the value of their patents compared to the managers, and that this is produced by the inventors in the large firms: the inventors in the larger firms exhibit a higher average difference in the evaluation of their patents’ value with respect to their managers than in the smaller firms. The inventors in academia and other non-profit research institutions behave like the small companies (See the PatVal-EU Report, 2005).

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