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Returns to Inventors

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ABSTRACT

A key input to inventive activity is human capital. Hence it is important to understand the monetary incentives of inventors. We estimate the effect of patented inventions on individual earnings by linking data on U.S. patents and their inventors to Finnish employer-employee data. Returns are heterogeneous: Inventors get a temporary reward of 3% of annual earnings for a patent grant and for highly-cited patents a longer-lasting premium of 30% in earnings three years later. Similar medium-term premia accrue to inventors who initially hold the patent rights, although they forego earnings at the time of the grant.

KEYWORDS: citations, effort, incentives, inventors, intellectual property, patents, performance pay, return, wages

JEL codes: O31, J31

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1 Introduction

A key input to inventive activity is human capital. Thus incentives for individuals to invest in acquiring appropriate human capital and to put their effort into inventive activities may be important. Therefore it is of substantial interest and significance to shed light on the monetary incentives to inventors provided by the labor market. While the incentives of firms to invest in innovation have been established in numerous studies on the returns to R&D and the value of patents to firms, very little is known of how the inventive individuals behind these patents are rewarded for their effort. We take a step towards filling this gap by empirically examining the financial returns to patent inventors and the heterogeneity of those returns. We construct a dataset where U.S. (USPTO) patents and their inventors from the NBER patents and citations data file (Hall, Jaffe and Trajtenberg, 2001) are linked to Finnish employee-employer data containing detailed information on personal characteristics and earnings as well as information on the employers from 1988 to 1999. This data gives us the opportunity to explore, ex-post, the existence of monetary incentives for individuals to invent, by estimating the effect of patent grants on their earnings.

The sources of financial returns to employee-inventors include incentive schemes that are directly tied to patenting, as well as indirect effects on earnings through an improved position of the individual in the labor market. Compensation schemes that are tied to signals of effort and successful outcomes are particularly important when tasks are hard-to-monitor, including research- and development activities. A nascent literature (Lerner and Wulff 2007 and Lach and Schankerman 2008) exists on the effect of different ex ante incentive schemes on innovative performance. Once granted, a patent provides a publicly observable signal about the ability of the inventor and may lead to wage increases, for example, through increased outside offers and bargaining.[1] We therefore expect wages to respond to patenting via direct compensation or labor market effects. Taking an ex-post view and measuring the level of rewards provided by the labor market and existing incentive schemes is a key input in the design of new ones. Our research therefore complements the literature studying the effects of incentives on innovation output.

We have access to a unique dataset of individuals, where we observe individuals' earnings and the USPTO patent grants for their inventions throughout the time period from 1991 to 1999 (together with citations received up to 2002). This enables us to take a novel and holistic approach to evaluating the existence of monetary incentives of invention and estimate the effect of patent grants and patent citations on individuals' earnings. Patents offer a convenient, if not trouble-free, window on individual inventiveness and have been exploited in economic research at least since the 1950s (Schmookler 1957, Griliches 1990). Using citations to patents improves this measure by accounting for patent value (see eg. Trajtenberg, 1990). Monetary rewards to patenting may take various forms, including one-time bonuses, value-contingent payments, stock options, and wage raises. Thus the returns can be both temporary and long-term, and may be realized some time after the patent grant. Therefore, we adopt a flexible specification including up to six lags of granted patents to allow us to identify the timing of the returns. Given what is known about the heterogeneity in the value of patents, and about the time it

[1] To the extent that such revelation of information leads to better employee-employer/task matches, those returns are also partly social returns.

takes to learn this value, we expect the signal to become more informative as some time passes from the patent grant, and that citations to a patent (shown to be a good indicator of patent value) are a more informative signal than a simple patent count.

With panel data at the individual level and variation over time in patent grants, we can control for unobserved individual heterogeneity with fixed effects, and remove the ability bias, which is often a problem in exercises of similar nature, such as in estimating the returns to schooling (see e.g. Card 2001). The lag between the time of an invention and the patent grant enables us to treat granted patents as predetermined variables. Our specification also survives the strict exogeneity test, and the fact that first-differences and fixed effects results are very similar lends further confidence that strict exogeneity is satisfied. This provides some indication that what we measure is the causal effect of patent grants on wages.

We find that inventors get a temporary reward of about 3% of their gross annual earnings in the year of the patent grant, presumably corresponding to a one-time bonus for being awarded a patent. In addition, patent grants result in an average of a 4-5% premium in annual earnings three to four years after the patent grant, and remaining for at least the following two years, possibly representing a permanent wage increase. These results are robust to 1) including any number of lags from 4-6; 2) including a firm-level measure of invention to control for possible firm-level wage effects that are due to invention; 3) controlling for the average wages in the firm or industry; 4) excluding the year 1999, which may be affected by the IT boom of the turn of the millennium; and 5) including a large control group of non-inventors.

We also find that, behind the average effect we identify, there are interesting differences in returns, depending on the quality or value of the patent as measured by expected lifetime citations. These quality-dependent returns are first realized three years after the granting of the patent, coinciding with the time it typically takes to learn the value of a patent (Pakes 1986, Lanjouw 1998). Similar to the value of patents to firms, and in line with the findings of Harhoff and Hoisl (2007), the returns to inventors seem heavily skewed, and linked to citations (see Trajtenberg 1990 and Hall, Jaffe and Trajtenberg 2005). Indeed, it is only the highest quality patents that yield positive returns for inventors. When we include categories for patent quality, we find that patents with 20-30 citations generate a premium of 17.5% in annual earnings in the 6th year and patents with over 30 citations generate a premium of over 30% from the 4th year onwards. In contrast, patents with less than 20 citations seem to generate no returns. Returns to inventors are thus very heterogeneous, and tied to observable signals of the quality of the patent.

It seems natural to think of these rewards to patenting as part of "pay for performance", the increase in which has recently been shown to explain a large part of growth in male wage inequality in the U.S. from the 1970s to the 1990s (Lemieux, MacLeod, Parent 2008). One can also view patenting and the citations a patent receives as observable signals of an employee's ability or productivity. In models of learning about worker ability, e.g. Farber and Gibbons (1996), the job market obtains signals of worker ability over time (usually assumed to be unobservable to the econometrician) and wages respond to these signals. In our application, these signals, represented by patents and their quality, are public information and thus observable also to the researchers. Our results indicate that they do play a large role in determining inventive individuals' remuneration. These results are also in line with survey evidence on the incentive schemes for inventors in Finnish firms, explaining e.g. the immediate reward due to a patent being granted.[2] Furthermore, the results indicate compliance with the law on employee inventions in Finland, which states that inventors are entitled to compensation that depends on the value of the invention.

Most of the patents in our sample are assigned to corporations, but there is a small fraction where rights are unassigned or assigned to individuals, presumably the inventor.[3] We also analyze the dependence of the returns on the ownership of the intellectual property by comparing the returns to inventors who initially own the patent to the returns to those whose patent is assigned to an organization. Individuals and firms may have different capabilities to internalize the revenues from an invention, and the overall private returns from an invention may be greater for patents assigned to firms (Grönqvist, 2009). On the other hand, individuals whose patents are assigned to firms only receive a share of the rents. We find that those inventors who initially own their patents first forego some of their earnings, but eventually earn substantially higher rewards than those inventors who do not have the intellectual property rights over their invention: The returns to inventors

[2] Pekari (1993) examines employee inventions through case studies and interviews of 16 actively patenting companies (6 large, 5 medium, 5 small) in Finland. In 11 of the 16 companies (and in all of the large companies), there were explicit rules for rewarding employees for their inventions. In large companies, the reward structure typically had three phases: at the time of the notice of invention, a fixed reward of 1000-2500 FIM (160-420 Euros); at the time of the patent grant, a fixed reward of 2200-10000 FIM (360-1700 Euros); and as the value of the invention is revealed over time, a special value-contingent reward. The fixed fees were designed so, that in most of the cases, they would represent "reasonable compensation" for the inventor and no special reward would be paid. However, if the invention later proved to be of exceptional value, the inventor would have been entitled to a special reward. This special reward is determined by the fraction of the value of the invention that the inventor is entitled to, depending on the employee's overall role. The value-contingent reward was typically paid 2-3 years after the patent grant. In small and medium-sized companies, while fixed rewards for invention and patenting were less common than in large firms, special value-contingent rewards for all patented inventions were used.

[3] This can be the case when the invention falls outside the activities of the employer.

who initially own their patents is of the order of a 15-30% premium in gross earnings in the 5th to 6th year after patent grant (in contrast to the 4-5% average premium for those who do not). This difference is not explained by higher quality of inventor owned patents: The number of citations to inventor-owned patents is on average lower than to company-owned patents. This finding suggests that conditional on the quality of the patent, owning the intellectual property significantly increases the returns to inventors.

A number of other findings are also of potential interest. We find that employer changes after the patent grant do not affect the returns, i.e. regardless of whether the inventor stays with the firm where the invention is made or changes employers, the same returns accrue. Looking at gender differences, we find a male-female wage gap of 20%, even conditional on being an inventor. Regarding the difference in returns for males and females, we find the same immediate reward, but no long term returns for females. This could, of course, be due to a number of factors, e.g., females working in different industries and different firms, and we find evidence of heterogeneity between firms. We find that there are no significant long term returns in the pharmaceutical sector, and some evidence that only the most active patenting firms pay a premium for past patents. We also find that inventors have particularly high returns to age (experience), of the order of 10-12%, possibly mirroring the results of Møen (2005), but the returns to tenure are low (less than 1%).

We proceed as follows. In Section 2 we review the related literature. In Section 3 we describe the data. In Section 4 we present the empirical framework and in Section 5 the results. We conclude in Section 6.

2 Literature review

There is evidence that inventors are driven by profit motives. In the 19th century, individual inventors reaped the benefits of their inventions through own commercialization and through licensing (Khan and Sokoloff, 1993). As inventions became more technical and capital-intensive, inventive activity (and individuals) moved into larger organizations (Lamoreaux and Sokoloff, 2005). Today, inventors mostly invent as a part of their job and inventive activity is to a large extent organized in R&D laboratories in firms and other R&D performing organizations. Thus, for today's employee-inventors, the financial incentives to invent are provided through employer compensation and through the labor market.

Incentives to invent are not limited to financial gains, but can also be non-pecuniary. Rossman (1931) reports the survey responses of a group of over seven hundred inventors, including the most prominent inventors of the time, who were asked for their motives and incentives to invent. The most commonly cited reason was "love of inventing", followed by "the desire to improve existing devices". "Financial gain", although clearly important, was only the third most frequently mentioned motive. There is clearly an element of current satisfaction ("on-the-job-consumption") that research activity provides in addition to any financial rewards, as also noted by Levin and Stephan (1991), and emphasized in biographies of past inventors (Rossman 1931). Similar evidence is provided by Stern (2004), who finds that scientists employed by firms in fact "pay to be scientists", i.e., accept lower earnings in return for being able to pursue individual research agendas and publish in scientific journals.

The importance of non-pecuniary incentives not-withstanding, economists have studied the role of monetary incentives in the innovative process. Aghion and Tirole's (1994) incomplete contracts - analysis, for example, normalizes the non-monetary incentives to a constant, and studies the effects of monetary incentives. The standard theoretical foundation for providing employees with (monetary) incentives comes from principal-agent models. These models suggest that compensation should be tied to an informative signal of the level of effort (Holmström, 1979). While incentive schemes have been subject to empirical research (e.g. Bandiera, Rasul and Barankay 2005, and Lazear 2000), they have been less studied in the context of innovation. An important exception is Lerner and Wulf (2007), who analyze how corporate R&D managers' compensation affects innovation in firms. Their key finding is that when the corporate R&D head has substantial firm-wide authority over R&D decisions, long-term incentives such as stock options are associated with a higher level of innovation (more heavily cited patents, patents of greater generality and more frequent awards). Another important exception is Lach and Schankerman (2008) who study the effect of university royalty sharing schemes on university patenting in order to understand the importance of monetary incentives for university inventors. They find a positive correlation between the royalty share granted to faculty scientists (inventors), and university patenting. These papers differ from ours in that they use direct measures of monetary incentives where we use outcomes, and in that they use aggregate (firm or university level) data where we use individual level panel data. These authors study the effects of incentive schemes on inventors' performance, whereas we seek to measure the aggregate level of all incentive schemes - thus our work complements theirs.

The provision of incentives is not the only reason why the labor market would reward inventors. For example, being a patent inventor may work as a signal of the individual's ability and productivity and so result in a wage premium. Furthermore, such signaling can lead to improved firm-worker matches, thus raising earnings. Additionally, an invention represents knowledge, some of which is tacit and embedded in the individual, and this knowledge should earn a return in the labor market. A related point concerns knowledge spillovers: If firms want to prevent such spillovers, they may have to pay a wage premium to inventors in order to retain them. Evidence for this is provided by Møen (2005), who finds that while the technical staff in R&D-intensive firms first pays for the knowledge they accumulate on the job through lower earnings in the beginning of their career, they later earn a return on these implicit investments through higher earnings. At the same time, in order to benefit from incoming spillovers[4], firms are willing to pay a premium in order to acquire such workers, as shown by Andersson et al. (2006), who find that firms with high potential payoffs from innovation pay more in starting salaries than other firms in order to attract star workers (workers with a history of higher earnings and wage growth), and furthermore, that such firms also reward these workers for loyalty. Van Reenen (1996) finds that technological innovation leads to higher average earnings in innovating firms, and interprets the result in accordance with theories of rent-sharing.

Finally, as in many other countries, there is a legal framework that provides a basis to expect inventors to earn a return on the inventions they produce while employed

[4] Kaiser et al. (2009) provide evidence that firms hiring mobile R&D workers from patenting firms can benefit from incoming knowledge spillovers. They show that such workers contribute to an increase in patenting in the recipient firm and also that labor mobility of R&D workers increases the joint patenting activity of the firms involved.

(the law on employee inventions in Finland, 29.12.1967/656). While giving the right to the invention to the employer (in most cases)[5], the law also rules that the employee has the right to reasonable compensation from the employer for the invention, taking into account the value of the invention. Similar legal provisions exist e.g. in Germany, and have been studied recently by Harhoff and Hoisl (2007). They address a question that is closely related to ours: Using survey data on German inventors of EPO patents, they study how the characteristics of the surveyed patent affect the share of the inventor's salary received as compensation for that patent.[6] The survey responses from the inventors indicate that the average compensation for one patent is 1.8 percent of annual gross income, and for all patents an average of 8.3%.

3 Data

3.1 Matching USPTO and FLEED data

Our source of information on inventions and inventors is the NBER patents and citations data file (Hall, Jaffe Trajtenberg, 2001) on U.S. Patent Office (USPTO) patents. In the past few years, there have been some research projects making use of large scale inventors' data. Most notably, Trajtenberg et al. (2006) have developed a computerized

[5] Finnish law divides inventions into four groups in this respect: inventions in group A either came about as through a close relation with the job of the inventor, and utilization of the invention fits into the activities of the employer or came about as part of the job of the inventor (no matter whether the utilization fits into the activities of the employer or not). In this case, the employer owns the invention if it so chooses. Inventions in group B came about in a different relation to the job as those in group A, but fit into the activities of the employer. For these inventions, the employer has user rights, but must negotiate over any larger rights. Inventions in group C came about without a connection to the job of the inventor, but the utilization falls into the activities of the employer. The employer has then the right to negotiate over use rights first. Inventions in group D came about without a connection to the job of the inventor and the utilization does not fall into the activities of the employer. The employer has no rights in this case (Mansala 2008).

[6] Their survey contains a question about this share, but apparently no questions on levels of monetary compensation. Harhoff and Hoisl also offer a very nice discussion of legal compensation schemes for inventors in various countries.

matching procedure to identify inventors in the NBER patent data. Some studies have used smaller scale data: Kim, Lee and Marschke (2004) use matched firm-inventor data from the pharmaceutical and semiconductor industries to study the relationship between firm size and inventor productivity. We go a step further than the previous studies and match inventor data to the employee records in a longitudinal employer-employee dataset of the Finnish working-aged population (FLEED) that resides at Statistics Finland. The FLEED is a register-based dataset that contains detailed information on all Finnish individuals in the working age population and their characteristics, in particular their annual earnings, as well as firm-level information on their employers.[7]

The NBER patent data contains the names of all inventors of a given patent, and information on their address (at a minimum, the municipality of residence). In Finland, each resident is given a unique identifier (the personal identity code), which is contained in the Finnish Population Information System (FPIS) together with basic personal information, including the address and municipality of residence. With the aid of the Population Information System, inventor information from the NBER patent data can be linked to their personal identity codes. These personal identity codes are also contained in the FLEED (in encrypted form), enabling the linking of inventor information with it.[8] Those Finnish patents from the NBER data that are assigned to Finnish companies have also been linked to their assignee firms in the FLEED. This provides us with an additional link we can use to help us identify the inventors. In cases where the name and residence information in the inventor data matches more than one personal identity code

[7] Given the richness of the FLEED data it is impossible to detail its contents here. See Korkeamäki and Kyyrä (2000) for a description of the FLEED.
[8] The process of linking the inventor records to personal identification codes was done at the Statistics Finland by their own personnel under strict confidentiality, and we never had access to any information that would have enabled the identification of individual people from the data.

from the FPIS, we also utilize this link between the patent inventor and the patent assignee, allowing us to search for the correct personal identity code from among the employees of the assignee firm. Altogether, this information helps us in solving a key issue that has hampered progress in studying inventors: The matching of inventors from patent documents to other data.

We use USPTO patents rather than Finnish patents, because they should be more valuable. Grönqvist (2009) has estimated that the average value of a Finnish patent is of the order of only 5000€, reflecting the small size of the Finnish market. Using USPTO data will also make our results comparable to other studies using the same data.

The data construction proceeded as follows. Using the full name and the municipality of residence on the inventor record (as well as the full address where available), together with the patent application year, the FPIS was searched for matching records and all matching personal identity numbers were linked to the inventor record. For some, this resulted in a unique match, while for others a number of potential identity numbers matched the inventor information. In order to determine the right identity for the inventor, we utilized the link between the patent inventor and the assignee firm to search the personal identity codes of all the employees in the assignee for matches with those linked to the inventor record.

For those individuals for whom more than one personal identity number was found from the population register, the identification of the correct individual was based on the assumption that they are employees of the patent assignee firm. While we expect this to hold true for the majority, in some cases this may lead to misidentification of the inventor. Thus we may have assigned a patent to some non-inventors, and at the same time failed to assign the patent to its proper inventor. If this is the case, it introduces some measurement error into our patent variable and biases our estimates downward.

Unfortunately, though not surprisingly, we were unable to identify and link all the patent-inventor records to the employee records, for two reasons. First, for some inventor records, the search from the population register produced no match. This could be due to misspellings in the names or incorrect information for some other reason. Second, for some of those inventor records for which several matching identity numbers were obtained from the population register, more than one of these identity numbers were also found among the employees of the patent assignee firm. Without a unique match, we failed to identify and link the patent to any individual, so that these inventors are not included in our sample.

Taking from the NBER patents data all the patents whose country code is FI, and which were applied for between 1988 and 1999, and linking these patents to their inventors, whose country code is FI, we end up with 8065 inventor-patent records. From these, we manage to identify and link 5905 records to the FLEED, consisting of 3253 individuals. For our empirical analysis, we limit the sample to observations from the year 1991 onwards, because the linking of inventors and patents to the FLEED is based on the application year of the patent, but our analysis uses the grant year of the patent. The typical lag from the patent application to the grant is between one and three years, so for most of the cases, we are able to match a patent inventor to a granted patent from 1991 onwards. The resulting sample is an unbalanced panel, with 91% of the individuals appearing in the data for all the nine years, resulting in a total of 28212 observations.

3.2 Samples and descriptive statistics

The process described above generates our data on inventors, i.e., individuals that are listed as inventors in at least one USPTO patent during our observation period.[9] We limit our estimation sample to individuals who are full-time employees at the end of the years in which we measure their earnings (i.e. remove those classified as entrepreneurs, unemployed, students, retired, in military service or otherwise out of the labor market). Removing from the sample observations for which there are missing values in any of the variables we need, we are left with a sample of 15996 observations on 2156 individuals. For our full specification, which includes six lags of the patent variable, the sample consists of about 4938 observations on 1789 individuals.

Table 1a presents some descriptive statistics for this sample for the years 1991, and 1995-1999. We see that the individuals in this sample are predominantly male (92%), on average 39 years old in 1991 (45 years old in 1999), and employed by their current employer (tenure) for 8 years on average in 1991. The mean annual earnings in the sample is about 37 000 Euros (median 34 400) in 1991 and they increase throughout the time period, reaching over 50 000 Euros (median 44 900) in 1998 (all converted to 1999 money). The mean earnings in 1999 are at 80 000 Euros with a very high variance (median 44 900). Table 1b presents the descriptive statistics conditional on having been granted a patent that year: The number of individual inventors has almost tripled over the period of the 1990's from 196 to 560; the mean number of patents per inventor ranges from 1.2 to 1.4. The patent quality, i.e. the mean number of expected lifetime citations

[9] Some 11% of the individuals listed as inventors are in a managerial position and could e.g. be managers of a laboratory. It could be that they have their names on the patent as a matter of policy rather than through having been involved hands-on in the inventive process. Our view on this is that, to the extent that the laboratory manager is responsible for creating an environment that is conducive towards invention, they should be rewarded and we want to include them into our sample as inventors.

(see section 5.4 for an explanation) received per patent, varies around 13 and shows no particular trend. Table 1c presents the levels and fields of education for the sample. The inventors are fairly highly educated, with more than half of the inventors having a masters degree or a doctorate. Most of the inventors have an engineering degree (78%). Table 1d shows the number of observations in the main industry sectors represented in the sample, with 70% of the individuals working in the following 5 sectors: Manufacturing of chemicals and chemical products; machinery and equipment; radio, tv and communication; medical, precision, and optical instruments; and provision of business services.

The number of firms represented in the data is 224 in 1991 and 528 in 1999, with a total of 936 different firms over the whole time period. The distribution of the number of individuals per firm is skewed, with (in 1999) over 350 firms employing just one inventor, 60 firms employing two inventors, 30 firms with 3 inventors, and only three firms with more than 100 inventors.

[Tables 1a, 1b, 1c and 1d here]

In Figure 1 we present the histogram of the number of patents per inventor over our sample period. The great majority of them (60%) have just one patent over the whole time period, while about 20% have two patents and the most inventive of them as many as 23 patents. To gain further insight into this, Figure 2 presents a histogram displaying the frequency of observations with *n* patents. This distribution is also heavily skewed with a mass at zero patents: Almost 12993 observations with zero patents in a given year (not shown in the figure), 2422 observations with one patent, and 409 with two patents.

Figure 3 shows the distribution of citations for observations with at least one patent. This distribution is also heavily skewed to the left with a long right tail.

[Figures 1 - 3 here]

We have 127 inventor-patent grant observations where the patent is owned by the inventor(s) at the time of granting the patent, while the rest are observations where the patent is assigned to an organization (mostly companies, so we refer to these as corporate-owned patents). Comparing the number of citations by ownership we find that inventor-owned patents receive fewer citations than those owned by organizations: The mean number of citations for inventor-owned patents is 7.32 and that for corporate-owned patents 10.27.

4 The empirical framework

We estimate equations of the following form:

$$\ln(w_{it}) = X_{it}\beta + \sum_{j=0}^{\tau} \gamma_{j+1}\, patent_{i(t-j)} + \alpha_i + \mu_t + \varepsilon_{it}\,, \qquad (1)$$

where $ln(w_{it})$ refers to the log of annual wage income, X_{it} is a vector of person- and firm-level characteristics, α_i is an individual-specific unobservable fixed effect, possibly correlated with the variable patent, μ_t is a year dummy, and ε_{it} is the error term. Personal characteristics include the person's age and its square, a vector of 42 dummy variables for the level and field of education, gender, tenure with the current employer, and the number of months employed during the year. Firm characteristics include the sector of the firm, the number of employees in the firm, and its location regionally (NUTS2: 5 location dummies[10]).

The variable $patent_{it}$ is a variable capturing the individual *i*'s inventions in period *t*. The simplest measure of invention we use is a patent count, i.e., the number of patents granted in a given year in which the individual is listed as an inventor. Because inventions can affect earnings in subsequent years, not just in the year of the patent grant, we include τ lags of the patent variable in order to estimate any long-term wage effects of innovation. We experiment with as many lags as the data enables.

We also explore the implications of patent value or quality on the inventors' earnings by using forward citations to the patent. A number of studies have shown that there is substantial heterogeneity in the value of innovations, and that this distribution is highly skewed, e.g. by using patent counts and renewal decisions (Pakes 1986, Lanjouw 1998, Grönqvist 2007), survey questions on patent value (Harhoff, Narin, Scherer and Vopel, 1999), and from patent citations (Trajtenberg 1990, Hall, Jaffe and Trajtenberg 2005). Given that the returns to firms from patents are highly variable, one might expect that the rewards that employers pay to inventors are also based on the value of the innovation.

We use both the within and first-differencing transformation to identify the effect of patenting on an individual's wage. The key aspect is that any unobservable individual time invariant factors are removed by these transformations. Importantly, this relieves us of the ability bias typically encountered in the returns to schooling studies (see Card 2001 for a review of the schooling studies). Both the within and first-differenced estimators are

[10] The NUTS 2 is a five-level regional classification system of the European Union. In Finland the five major regions are: Southern Finland, Western Finland, Eastern Finland, Northern Finland, and Åland.

consistent under the assumption of strict exogeneity: $E[\varepsilon_{it} \mid Z_{i1},...,Z_{iT},\alpha_i] = 0$.[11] We expect no contemporaneous correlation between the error term and the patenting variable, because a patent granted in year *t* has in effect been (pre)determined before year *t*. The lag between the years of patent application and granting of the patent is on average 2 years in our data. Therefore the effort into developing the innovation has been put in at least a couple, probably more, years before the granting of the patent. One possible worry about the strict exogeneity condition is that future wage shocks may be correlated with the current period value of the patent variable, for example through labor markets treating patenting as a signal of (permanent or at least long-lasting) productivity. However, this is part of the effect we estimate and is captured by the inclusion of the lagged values of the patent variable. If, on the other hand, the realization of patents in the future is correlated with the contemporaneous error term in the wage equation, the strict exogeneity condition would be violated. This could happen, for example, through changes in jobs either within or between firms, if a job change results in a better match between inventor and firm and also improves the patent productivity of the inventor. We apply a test of strict exogeneity and do not reject it. Under this assumption, the individual fixed effects also take care of selection into the sample and thus make the use of a control sample of non-inventing individuals unnecessary. As one of our robustness tests, we include a large control group of non-inventors into our estimation sample: Our results are robust to this.

[11] First-differencing does not necessitate strict exogeneity. For a discussion, see e.g. Wooldridge (2002) ch. 10.6.

5 Results

5.1 Base specification

In Table 2 we present the results from estimating our base specification with the variable patent being the number of patents granted to individual *i* in year *t*. While our preferred estimation methods are fixed effects and first-differencing, we also report the results from pooled OLS for comparison. The pooled OLS estimate of the returns to inventors is 0.035, the fixed effects estimate is 0.016, and the first-difference estimate is 0.013. The magnitude of the OLS estimate reflects the upward bias generated from unobserved individual heterogeneity, as expected. These results indicate that the average increase in earnings due to having an invention being granted a patent is around 1.5%.

[Table 2 here]

Some of the control variable coefficients are of interest: The age premium (the return to experience) is relatively high (coefficient on age circa 0.1 and that of squared age -0.001) compared to the coefficient on tenure[12] (measured in years), which is only 0.002 – 0.009. The coefficient on the female dummy is -0.21 (OLS coefficient). Firm size has a positive effect on earnings (large firms pay higher earnings). Most of the year dummy-coefficients are significant, as are many of the education and sector indicators' coefficients.

In order to test whether inventors are rewarded already at the time of the patent application, we ran a specification where we also include the number of patent

[12] We also tried specifications including the square of tenure, which was mostly insignificant and did not affect our results.

applications together with patent grants in year *t*.[13] We find no significant effect of patent applications on earnings; the coefficient on the patent grants remains the same.

5.2 Including lags

We next investigate whether the effect of patenting on wage is a permanent increase in the wage level (e.g. a wage raise) or a temporary one (e.g. a bonus) by including lags of the patent variable. Including lags is also important because patent grants may be correlated over time and thus introduce an omitted variable bias when not included in the estimations (in other words, violation of the strict exogeneity).

We run a series of regressions where we include lagged values of the patent variable, experimenting with one to six lags. We also test the strict exogeneity assumption by including the lead of the patent variable in our fixed effect model, and by including the levels of the patent variables in our first-differenced model (see e.g. Wooldridge 2002, ch. 10.7.1). We cannot reject the null in either case. In Table 3 we present the results from the estimations with six lags.[14] The coefficients of the control variables (age, tenure, gender) hardly change. In all the estimations, the coefficient of the current value of patent remains positive, and in fact goes up (0.050 in OLS, 0.022 in FE, and 0.028 in FD). This suggests that there indeed is an omitted variable bias in the base specification results.[15] In addition, the fourth, fifth and sixth lags get a positive significant

[13] For these regressions, we are forced to exclude the most recent years of our data (1997-1999), because we do not observe the patent applications for patents granted after 1999.

[14] Results from specifications including up to 4 and 5 lags produce similar results. Specifications with less than 4 lags miss the positive effect captured by the 4th – 6th lags. Including a 7th lag reduces the significance of the estimates below 10%, although the signs are the same and magnitudes are close to those with fewer lags. This may be due to the fact that using 7 lags only leaves two years of data at our disposal.

[15] Intuitively, what happens in the base specification is that the (fourth – sixth) years after the patent grant are wrongly allocated into the control group of "no patent grant" – years, raising the average wage earned while in the control group, and thereby inducing a downward bias in the base specification patent coefficient.

coefficient in the fixed effects and first differenced regressions, ranging from 0.04-0.05. These results indicate that, first of all, there is a temporary wage increase in the year of being granted a patent in the order of just below 3%, and in addition to that, there appears to be a longer lasting, possibly permanent, effect increasing earnings from 4 to 5 percent four years after the invention is patented.[16] The fact that this wage increase comes a few years after the patent grant may be related to the fact that it typically takes three to four years to learn the value of the patent (see Pakes 1986 and Lanjouw 1998 for German, UK and French patents and Grönqvist 2007 for Finnish patents). For example, Pakes (1986) finds that only 1.2 (0.5)% of French patent owners learn that their patent has no value in the 3rd (4th) year of patent life, and that the probability of learning a better use of the patent is only 0.1 (0.0)% in the 3rd (4th) year of patent life. His respective numbers for German patents are even lower.

[Table 3 here]

5.3 Non-linear effects

Next, we investigate whether the returns to inventors depend on the number of patented inventions in a non-linear way, keeping in mind that in most cases our patent count variable takes on the values 0 or 1, with less than 4% of observations having a value of more than 1. Here we report the results from the fixed effects estimations.

First, we include the square and cube of the patent count in addition to the linear effect. In the specification without lags, the coefficient (standard error in parentheses) on the patent count is -0.027 (0.016), on the square term 0.023 (0.011), and on the cubic

[16] It seems very unlikely that the patent lags would capture nonlinear experience or tenure effects as our specification includes a quadratic function of age, and tenure. In addition, we have estimated a specification with squared tenure included, with identical results.

term -0.0017 (0.0013), indicating that there are no immediate returns for one patent grant, returns of 2.5% for two patents, 8% for three patents, and 15% for four patents. When we include the lags, and square and cubic terms of the lagged variables, the coefficients are no longer significant on these variables.

We also test for non-linear effects by including the number of patents granted in a given year as a categorical variable. While many of the estimated coefficients are not significant due to the small number of positive values in these categories, the results show that the effects of having 5 or more patent grants are particularly large (although significant, they are imprecisely estimated), corresponding to wage differentials of 35%-80% relative to having no granted patents. The coefficient on two patent grants is 0.037 (0.024) and on three it is 0.074 (0.049). In the specification with lagged values, the results that emerge as significant are the coefficients on the contemporaneous terms for five patents: 0.21 (0.12) and six patents: 0.86 (0.40), on the 4^{th}-6^{th} lags of the term for two patents (coefficients of 0.09 to 0.18), as well as the 5^{th} and 6^{th} lags of the term for one patent (0.07 and 0.04). While the results from these estimations testing for non-linear effects are plagued by the limited amount of variation for patent categories above two, they seem to indicate that there are particularly high returns for those inventors who get a large number of patents.

5.4 Accounting for the quality of the patent

The effect on earnings of having made a patented invention is likely to depend on the value of the patent. The number of citations received by a patent has been shown to be a fairly good proxy for the value of the patent,[17] so we run the regressions including lags of the number of citations received by the inventor's patents together with the current period patent count. Using citations suffers from the problem of truncation, as citations to a patent arrive over long periods of time, but we only observe them until the last year of the available data.[18] We adjust these citation counts using the results in Hall, Jaffe, and Trajtenberg (2001) to remove the effects of truncation. These adjustments provide us with an estimate of the total number of citations a given patent will receive in its lifetime. We acknowledge that these estimates will be somewhat noisy, because for the patents in our data we only observe citations for the subsequent 3-15 years. Typically, the prime citation years for a patent are roughly 3-10 years after the grant (Hall, Jaffe, and Trajtenberg, 2005). The less citation years we observe for a patent, the noisier these estimates are.

The results of these estimations are presented in Table 4. We find that between three and six years after the patent grant (and possibly permanently), the number of citations received has a positive effect on the inventor's earnings, with every 10 citations received increasing the inventor's wage by around 3-5% (the estimates from the FD estimation are slightly lower than from the FE, and only weakly significant). These results lend support to the notion that the returns to inventors depend on the value of the patent, and are realized three years after the patent grant once the value of the invention is learned. The immediate effect of the patent grant remains. Similar to the value of patents to firms, and in line with the findings of Harhoff and Hoisl (2007), the returns to

[17] For example, Hall, Jaffe and Trajtenberg (2005) find that both the patents to R&D and the citations to patents ratios significantly impact the market value of the patenting firm.
[18] Here we make use of the updates to the NBER patent data, available from Bronwyn H. Hall's website, allowing us to observe the number of citations received by the patents up until 2002.

inventors thus seem heavily skewed. These findings lend further support for the claim, originating from Trajtenberg (1990), that citations are a measure of patent value.[19]

[Table 4 here]

To study the link between patent quality and returns further, we categorized patents according to the number of citations they receive. These results, displayed in Table 5, offer evidence that returns to inventors are highly tied to patent quality: We find that patents in the two highest quality categories (21 – 30 and over 30 citations) receive high positive returns. Those in the category of 21-30 citations obtain returns of 17.5% in the 6th year. Those in the highest category start earning returns in the 3rd year after patenting (23%) that are increasing in time and reach 36% in the 6th year. Our point estimates indicate that inventors with patents that obtain no citations earn a negative premium throughout. Two of these (for the 2nd and 4th years) are significant.

These results are qualitatively in line with models that suggest that the job market learns an employer's ability over time and rewards it. While such learning is often (e.g. Farber and Gibbons 1996) modeled as unobservable to the econometrician, one could view patenting and citations as observable measures of learning, available to the job market, public as they are.

[Table 5here]

5.5 Reward mechanisms

To extend our analysis from the level of returns to inventors to the sources of returns, we do three things: First, we study whether it is changes of employer that yield the estimated

[19] Trajtenberg (1990) found that citations reflect the social value of inventions. We find that they reflect the private (inventor) value of inventions.

returns. As patents are public information, the granting of a patent may make the inventors “more visible” and/or more valuable to other employees and returns to inventors could then be realized through job changes. Second, patents are not just a measure of invention: They also dictate who has the intellectual property over a given invention at the time of the patent grant, and (not) owning the intellectual property may affect the return to inventors, keeping the value of the patent constant. These returns may be realized through a variety of mechanisms such as licensing fees or through the sale of the intellectual property rights, or simply by increasing the value of the individual in the job market. We therefore study the effect of (not) owning the intellectual property at the time of the patent grant. Concentrating on ownership of intellectual property at the time of patent grant allows us to capture also the returns to inventors generated through subsequent sale of the intellectual property rights. Finally, we change our dependent variable to include capital income. As discussed in the introduction, if patents are valuable to the employer and producing patents requires effort (that is hard to monitor or measure), the employer may resort to providing incentives that generate capital income as well. It should be noted that since 1995 in Finland, stock options have been taxed as income and not as capital gains and thus are included in the dependent variable in our earlier regressions.

Turning first to the question of returns due to employer changes: The data shows that about 4% of the individuals change employers in a given year, and that over the time period of six years (from 1993-1999), 22% of the individuals have changed employers at least once. To study the possibility that the returns to inventors are generated through changes in jobs, we include a series of indicator variables and interactions between them and the patent variables to capture the effect of job changes between the year of the patent grant and the year when income is measured. To illustrate, consider an individual who obtained one patent three years ago, and changed her job last year. For her, the interaction between the job change indicator and the count of patents obtained three years ago would take the value one. This interaction allows us to separately identify the returns coming from patents obtained three years ago to those individuals who have subsequently changed jobs and to those who have not. Adding these variables into the specification containing lags of patent counts, we find that neither any of the new indicators, nor any of the interactions obtains a significant coefficient. Furthermore, our point estimates for the patent count variables are virtually unchanged. While this result suggests that actual job changes do not generate any extra returns to inventors, it does not mean that the existence of the possibility of changing jobs would not be a causal factor behind the returns we estimate.

In contrast, we do find that the ownership of intellectual property rights is a significant mechanism through which the returns to inventors are generated. We separate the patents into two classes: Those owned by a company (whether the employer of the inventor(s) or some other) at the time of the patent grant, and those owned by the inventor(s). We then re-estimate the model with lags of patent counts for both types of patents. The coefficients of the patent variables from both a fixed effects and a first-difference estimation of this specification are reported in Table 6. From that Table it is obvious that the reward structures are different when we condition for ownership: Inventors who initially own the patent first forego some of their earnings (possibly due to efforts in developing and commercializing the invention), but later earn returns higher than those earned by inventors of patents owned by a firm. Patents initially owned by the inventor(s) yield negative returns in the year of the patent grant and the year after that (inventors forego 7 and 15% of their annual earnings in these years), but later yield returns of circa 15% in the 5th year after patent grant (the point estimate in the FE model is 20%, but insignificant), and returns of around 30% in the 6th year (the point estimates are similar from both FE and FD, but the first-difference estimator is insignificant). The coefficients for the patent count variables when the inventor is not the initial owner are very close to those we obtained earlier (see Table 3), with returns in years 4-6 after the patent grant between 3.5 (6th year in the fixed effects regression) and 5.1% (5th year in the fixed effects regression). These differences in returns are not explained by the inventor-owned patents being of higher quality: As reported above, the number of citations is lower for (initially) inventor-owned patents than others.

A possible explanation for the initial negative returns to inventors who own their patents is that after obtaining a patent, they invest in increasing the value of the patent. Such investments could include development of the technology, spending time informing potential buyers about the technology and/or organizing the licensing or sale of the patent. Such activities could lead to a short-term decrease in earnings.

[Table 6 here]

Finally, turning to the question of whether inventors are rewarded through capital income -generating mechanisms, we re-estimate our model by changing the dependent variable to be the logarithm of the sum of wage and capital income (instead of being the logarithm of the former only). Estimating the model with lagged patenting variables (and a fixed effects estimator) we find that the coefficients of the lags for 4th to 6th year are significant (4th year only at 7% level, others at 1% level) with point estimates of 0.038, 0.052 and 0.04. These are all slightly lower than those reported in Table 3. Converting these per cent returns to monetary rewards we find that the monetary rewards at the wage level are almost exactly the same as when including both wage and capital income: Using the mean wage and capital income over the years 1997-1999 as our base, the estimated monetary returns at the wage level are 2550€ in the 4th year after the patent, 3260€ in the 5th and 2900€ in the 6th. These compare to monetary returns of 2560€, 3500€ and 2700€ when capital income is included in the dependent variable. It thus seems that the job market does not reward inventors through capital income. One reason why we find no extra returns in capital income is probably that stock options are in fact taxed (and reported) as annual wage income.

5.6 Robustness

Finally, we perform a couple of estimations to check the robustness of our results and examine some alternative explanations for them. We first test whether our results remain once we control for firm-level rent-sharing due to patenting, as found by van Reenen (1996). We also include the average wage in the firm (and alternatively in the industry sector) in which the individual works to control for average earnings growth in firms and sectors. We then examine whether the results are solely due to the IT-boom of the late 1990s, affecting only some of the firms and sectors in the sample. We also check whether men and women earn similar returns for their inventions. Finally, we check that our results are robust to including a random sample of controls; we append a large random sample of individuals who are employed at R&D-performing firms, but who do not invent, and perform all of our estimations for this sample.

First, given the result of van Reenen (1996) that innovation in a firm leads to higher average wages (interpreted as higher wages for all employees), and given that our goal in this paper is to estimate the returns to those individuals who make the inventions, we want to remove the possible concern that the returns we estimate are a reflection of firm-level rent-sharing.[20] To accomplish this, we include a variable for the number of patents granted to the firm in year t, together with lagged values of it. None of the coefficients on the firm patent variable are significant, while all our other results remain as before, thus eliminating concerns that it is the firm-level effect that is driving our results. Similarly, when we control for firm average wage (and industry average wage), our main results on the earnings premiums remain.

Second, given that the late 1990s (and particularly the year 1999) was a period characterized by sharply rising market values in the IT-sector (the IT-boom), it is worthwhile to check whether only these years, or these particular sectors, are the ones when and where inventors earned returns. In order to allow us to keep our specification with all the six lags, we only remove the year 1999 from the sample. Doing so hardly affects our results: The coefficients (standard errors) on the 4th, 5th, and 6th lags are: 0.06 (0.03), 0.04 (0.02) and 0.05 (0.02). We also test whether the returns are different for different sectors of the economy; we interact our patent count and its lagged values with variables for the main industries in our sample: Machinery, metals, chemicals, IT, and medical instruments. The direct effects of the patent counts remain as before, and only a few significant differences emerge between the sectors: In particular, the medical instruments sector stands out as not providing any medium-term returns to patenting

[20] Although, given that the sample contains individuals from the same firm who get patents that year and those who don't, the results are not likely to be merely the result of firm-level wage effects.

(negative significant coefficients on the interactions with the 4th-6th lags of the same magnitude as the direct effects). On the other hand, the IT-sector does not stand out as being different from the average.

To check whether the returns we estimate are driven by the few firms that are the largest patenting firms in Finland, we also perform our estimations removing from the estimating sample the observations from the largest two and largest three patenting firms (losing more than one third of observations). We find that none of the patent variables remain significant, which, while pointing towards the fact that it is especially these large patenting firms that pay returns to inventors, could also be due to the fact that we have removed most of the patent variables with positive values and are left with very little variation in our data.

When we allow the returns to be different for women and men (by taking interactions of gender with the patent count and its lags), we find that while the "bonus"-reward is not significantly different for the genders, the estimated long-run returns are driven by returns to men, not women. (The interactions for females are negative and significant and of the same magnitude as the direct patent count effects).

Finally, our results are robust to including a random sample of non-inventors from the same firms. With a sample of over 70 000 individuals (nearly 200 000 observations), all of our qualitative results remain, with the additional result that the coefficient on the 3rd lag is now significant in all of the estimations. The estimated coefficients go up in all specifications: Their magnitudes are 1.3-1.5 times the ones from the estimations on the sample of inventors.

6 Conclusions

The engine of economic growth is technological progress; the engine of technological progress is human inventiveness. We address the question of the returns to individual inventors by estimating the effect of obtaining a U.S. patent on the earnings of Finnish inventors over subsequent years. We investigate the timing and nature of these returns, and their dependence on the quality of the invention and on the ownership of IPRs.

Our results indicate that, there is a close to 3% temporary increase in earnings in the year the patent is granted, probably representing a one-time bonus, and a 4-5% increase in earnings three to four years after the patent grant, which remains there for at least the following two years, and possibly represents a permanent wage increase. We also find that the returns to being a patent inventor depend strongly on the quality or value of the patent as measured by the expected lifetime citations received by a patent. Highest-quality patents generate high returns to inventors while low-quality patents generate no or even negative returns. These quality-dependent returns are first realized three years after the granting of the patent, coinciding with the time it typically takes to learn the value of a patent. We also find that the returns to inventors depend not only on the quality of the invention, but also on ownership of intellectual property: Having ownership of the intellectual property when the patent is granted first yields negative returns but later increases the estimated returns in years 5-6 after the patent grant 4-6 fold, from around 4% to between 15 and 30%. This result is not explained by quality differences between inventor-owned and other patents.

Our results can thus be summarized in the following three points: First, returns to inventors are very heterogeneous, with low-quality patents yielding no, and high-quality patents yielding high returns; second, that while a patent grant is accompanied by a small bonus reward, the main part of the returns accrue to the inventors only after the quality of the patent is revealed; and third, that it is not only the act of invention that yields returns, but also the ownership of the intellectual property, as the returns to those inventors who own their patents are much higher than the returns to inventors whose employer has the rights on the intellectual property.

The results are consistent with the possible explanations presented in the introduction. One, firms' optimal design of incentive compensation schemes may be such that it gives rewards for observed signals of effort, and patent grants and the revealed quality of the patent in later years work as such signals. Two, patents and in particular their later-revealed quality may work as important signals of individual ability, and part of the later wage premium may be a result of the labor market effect of public learning of individuals' ability and productivity. Three, the results are in line with the law on employee inventions in Finland.

The results indicate that incentive mechanisms for inventors in Finland are such that they promote invention and direct effort towards high-valued inventions. As Finland is one of the countries that has improved its rate of invention, measured by U.S. patents, the most over the last decades (Trajtenberg 2001), understanding the role of monetary incentives in bringing this change about may offer lessons of more general applicability.

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Figure 1. Total number of patents in 1991-1999 per inventor

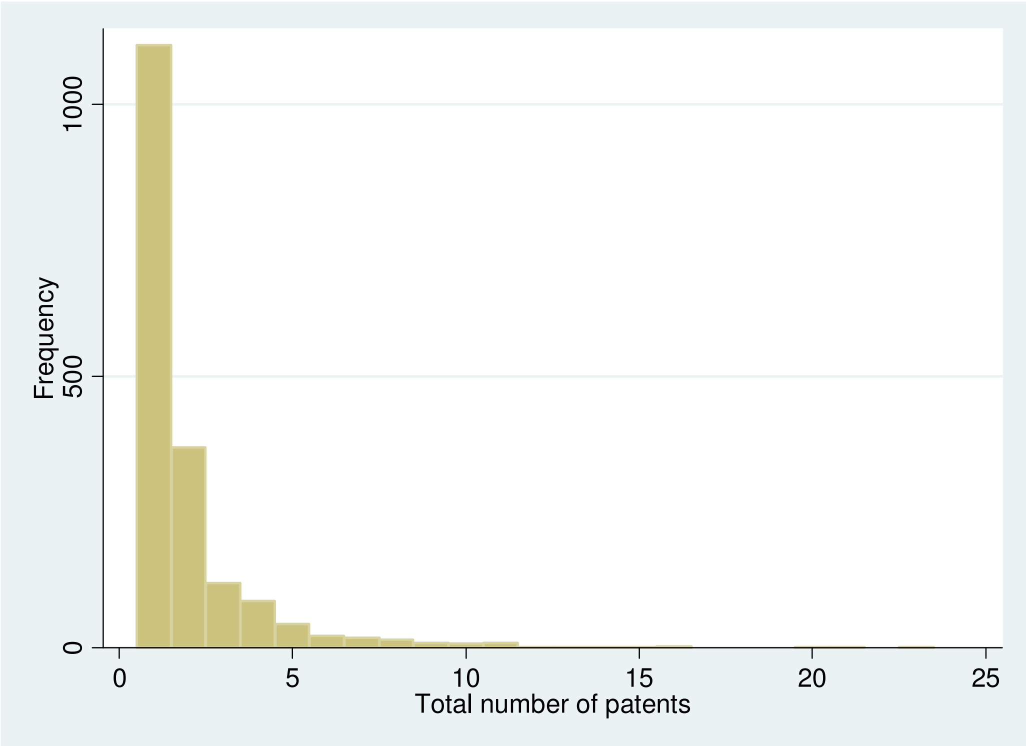
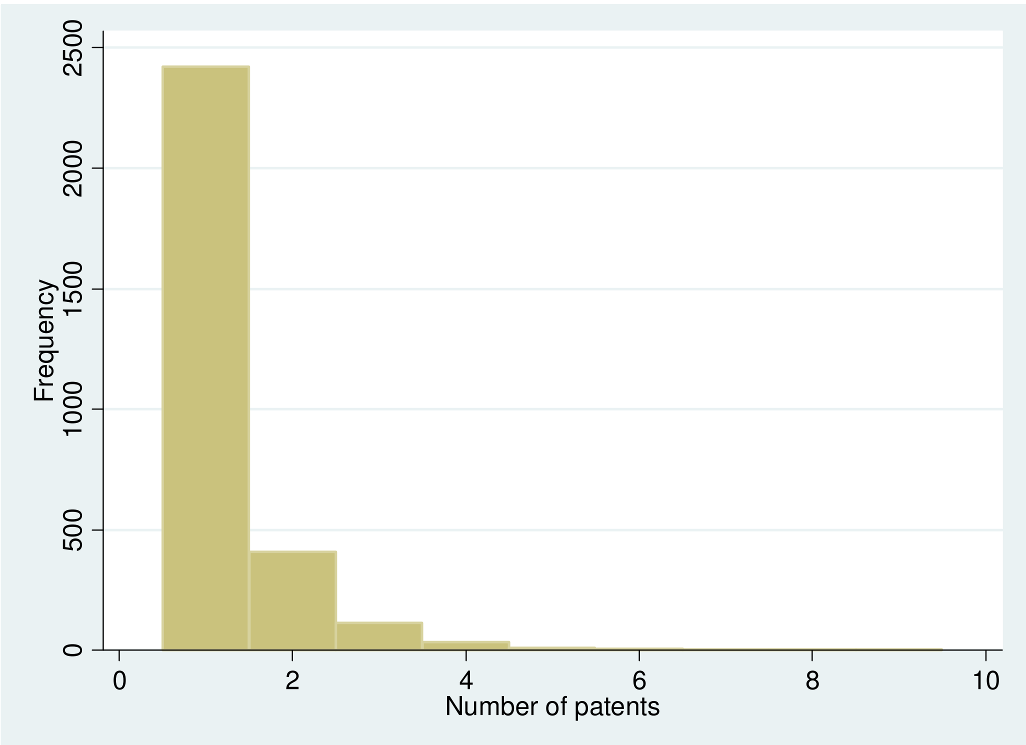


Figure 2. Number of patents per observation



Notes: Observations with 0 patents (12993) excluded from the graph

Figure 3. Number of forward citations (conditional on patents > 0)

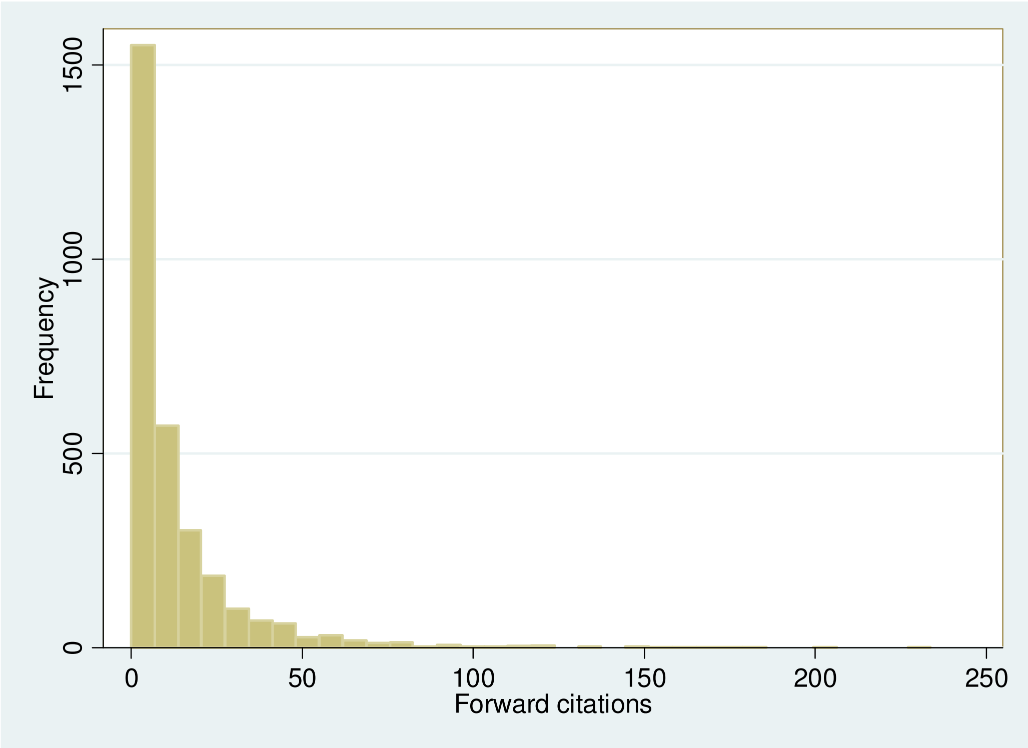


Table 1a. Descriptive statistics

Variable	1991	1995	1997	1998	1999
EARNINGS	37468	41280	46215	52287	79556
	16299	18427	36234	44612	260253
PATENTS	0.15	0.19	0.26	0.33	0.42
	0.44	0.51	0.54	0.68	0.81
CITATIONS	1.54	2.64	2.50	3.45	3.84
	5.86	11.95	8.60	13.19	14.16
AGE	37.7	40.9	42.7	43.5	44.3
	7.8	8.2	8.2	8.0	7.9
FEMALE	0.08	0.07	0.07	0.07	0.07
	0.27	0.26	0.26	0.26	0.26
TENURE	8.6	10.4	11.3	11.8	12.3
	7.4	8.0	8.3	8.4	8.5
MONTHS WORKED/YEAR	11.9	11.9	11.9	11.9	11.7
	0.75	0.79	0.68	0.70	1.57
FIRM SIZE (emp/100)	26.4	23.6	28.2	28.5	28.0
	22.3	25.3	34.8	35.3	38.8
Observations	1567	1877	1896	1866	1825

Notes: The statistics shown are means with standard deviations are below. *Earnings* is real annual work income (in 1999 Euros), *patents* is the number of patents granted, *citations* is the number of citations received, *age* is the age of the inventor, *female* is a dummy equal to one if the inventor is female, *tenure* is the number of years with the current employer, and *months* is the number of months in employment during the year, and *firm size* is the number of employees in the firm in hundreds.

Table 1b. Descriptive statistics conditional on having a patent grant that year

Variable	1991	1995	1997	1998	1999
EARNINGS	43446	43825	49080	53577	72322
	20718	20343	22558	48189	167175
PATENTS	1.22	1.25	1.18	1.28	1.38
	0.51	0.62	0.50	0.75	0.91
CITATIONS	12.3	17.4	11.3	13.5	12.5
	12.0	26.2	15.3	23.3	23.3
AGE	41.7	41.8	42.4	42.7	42.8
	8.3	7.9	7.7	7.9	8.4
FEMALE	0.06	0.07	0.04	0.08	0.10
	0.24	0.25	0.20	0.26	0.30
TENURE	11.5	11.4	11.7	10.9	11.3
	8.0	7.8	7.9	7.8	8.3
MONTHS	12	12	12.0	11.9	11.7
	0	0	0.4	0.6	1.5
FIRM SIZE (emp/100)	27.5	25.7	31.8	34.9	34.7
	24.3	23.4	36.9	38.9	43.0
Observations	196	284	421	478	560

Notes: The statistics shown are means with standard deviations are below. *Earnings* is real annual work income (in 1999 Euros), *patents* is the number of patents granted, *citations* is the number of citations received, *age* is the age of the inventor, *female* is a dummy equal to one if the inventor is female, *tenure* is the number of years with the current employer, and *months* is the number of months in employment during the year, and *firm size* is the number of employees in the firm in hundreds.

Table 1c. Education of inventors

Levels of education	**%**
Upper secondary	8.54
Lowest level tertiary	9.02
Lower-degree level tertiary	21.8
Higher-degree level tertiary	43.1
Doctorate	13.1
Not known or unspecified	4.46

Fields of education	**%**
General Education	2.04
Humanities and Arts	0.43
Social Sciences and Business	1.34
Natural Sciences	10.7
Engineering	77.9
Agriculture and Forestry	0.81
Health and Welfare	2.09
Services	0.16
Not known or unspecified	4.46

Table 1d. Main industry sectors in the sample

	Class	Obs.	Percent
Manufacturing:			
Chemicals and chemical products	24	1907	11.9
Machinery and equipment	29	3741	23.4
Radio, TV and communication	32	2992	18.7
Medical, precision and optical instruments	33	1173	7.3
Other business activities (services)	74	1328	8.3
All remaining sectors		4855	30.4
Total		15996	100

Table 2. Base specification

	OLS	FE	FD
PATENTS	0.0354***	0.0161**	0.0129**
	0.0076	0.0072	0.0061
AGE	0.110***	0.129***	
	0.008	0.008	
AGE^2	-0.0011***	-0.0011***	-0.0014***
	0.0001	0.0001	0.0002
TENURE	0.0068***	0.0093***	0.0018
	0.0014	0.0013	0.0016
FEMALE	-0.213***		
	0.0228		
MONTHS	0.114***	0.0901***	0.0870***
	0.009	0.007	0.009
FIRM SIZE	0.0008***	0.0023***	0.0009**
	0.0003	0.0003	0.0003
Constant	6.724***	5.853***	0.166***
	0.22	0.219	0.0157
Observations	15996	15996	13419
Individuals	2156	2156	2077
R-squared	0.33	0.23	0.06

Robust standard errors below
*** p<0.01, ** p<0.05, * p<0.1

Notes: The dependent variable is log annual wage income. All regressions include dummies for the field and level of education, dummies for the sector of the firm, dummies for the firm's regional location, and year dummies. OLS are the results from pooled OLS estimations with clustered standard errors, FE are the results from using the within (fixed effects) estimator, and FD are the results from the first-differenced regressions.

Table 3. Including lags

	OLS	FE	FD
PATENTS	0.0494***	0.0235	0.0275*
	0.0126	0.0144	0.0148
PATENTS (t-1)	0.0005	-0.0052	0.0035
	0.0167	0.0218	0.0232
PATENTS (t-2)	-0.0033	-0.0237	-0.0252
	0.0143	0.0225	0.0249
PATENTS (t-3)	0.0050	0.0126	0.0080
	0.0206	0.0196	0.0214
PATENTS (t-4)	0.0328**	0.0427**	0.0421*
	0.0144	0.0212	0.0218
PATENTS (t-5)	0.0203	0.0552***	0.0468**
	0.0148	0.021	0.0199
PATENTS (t-6)	0.0126	0.0493***	0.0522**
	0.0125	0.0176	0.0206
AGE	0.113***	0.202***	
	0.0206	0.0458	
AGE^2	-0.0012***	-0.0017***	-0.0016***
	0.0002	0.0005	0.0006
TENURE	0.0063***	0.0079***	0.0067***
	0.0017	0.0022	0.0021
FEMALE	-0.225***		
	0.0348		
MONTHS	0.0177***	0.0067*	0.0044
	0.0065	0.0037	0.0045
FIRM SIZE	0.0007	0.0042***	0.0035***
	0.0005	0.0009	0.0010
Constant	7.768***	4.578***	0.186***
	0.446	1.177	0.057
Observations	4938	4938	3126
Individuals	1789	1789	1639
R-squared	0.23	0.08	0.035

Robust standard errors below
*** p<0.01, ** p<0.05, * p<0.1

Notes: The dependent variable is log annual wage income. All regressions include dummies for the field and level of education, dummies for the sector of the firm, dummies for the firm's regional location, and year dummies. OLS are the results from pooled OLS estimations with clustered standard errors, FE are the results from using the within (fixed effects) estimator, and FD are the results from the first-differenced regressions.

Table 4. With citations

	OLS	FE	FD
PATENTS	0.0398***	0.0286**	0.0270*
	0.0125	0.0136	0.0145
CITS (t-1)	0.0009	-0.0006	-0.00002
	0.0012	0.0015	0.0017
CITS (t-2)	0.0012	0.0011	0.0003
	0.0008	0.0017	0.0021
CITS (t-3)	0.0025	0.0035*	0.0023
	0.0015	0.0018	0.0021
CITS (t-4)	0.0026*	0.0033*	0.0029
	0.0014	0.0018	0.0021
CITS (t-5)	0.0014	0.0042**	0.0033*
	0.0013	0.0018	0.0019
CITS (t-6)	0.0020	0.0050**	0.0042
	0.0020	0.0024	0.0026
AGE	0.111***	0.179***	
	0.0207	0.0457	
AGE^2	-0.0011***	-0.0015***	-0.0014**
	0.0002	0.0005	0.0006
TENURE	0.0062***	0.0076***	0.0064***
	0.0017	0.0021	0.0021
FEMALE	-0.224***		
	0.0348		
MONTHS	0.018***	0.0052	0.0027
	0.0065	0.0044	0.0052
FIRM SIZE	0.0007	0.0043***	0.0035***
	0.0005	0.0009	0.0010
CONSTANT	7.801***	5.114***	0.170***
	0.4490	1.185	0.0565
Observations	4938	4938	3126
Individuals	1789	1789	1639
R-squared	0.24	0.08	0.04

Robust standard errors below
*** p<0.01, ** p<0.05, * p<0.1

Notes: The dependent variable is log annual wage income. All regressions include dummies for the field and level of education, dummies for the sector of the firm, dummies for the firm's regional location, and year dummies. OLS are the results from pooled OLS estimations with clustered standard errors, FE are the results from using the within (fixed effects) estimator, and FD are the results from the first-differenced regressions.

Table 5. Fixed effects regression with patents classified according to no. of citations

	NO CITES	0 < CITES ≤ 10	10 < CITES ≤ 20	20 < CITES ≤ 30	CITES > 30
CURRENT	-0.019	-0.039	0.016	0.014	0.097
	0.033	0.026	0.052	0.093	0.088
LAG1	-0.056	-0.027	-0.010	-0.078	0.034
	0.045	0.033	0.056	0.131	0.095
LAG2	-0.127**	-0.045	-0.038	-0.131	0.086
	0.064	0.039	0.054	0.125	0.135
LAG3	-0.077	-0.023	0.013	0.001	0.228*
	0.054	0.030	0.064	0.129	0.125
LAG4	-0.101*	-0.015	-0.025	0.075	0.315***
	0.056	0.031	0.061	0.124	0.118
LAG5	-0.073	0.038	0.044	0.131	0.327***
	0.055	0.028	0.057	0.124	0.112
LAG6	-0.073	0.019	0.007	0.175**	0.363**
	0.053	0.023	0.030	0.078	0.158
Constant	4.800***				
	1.242				
Observations	4938				
Individuals	1789				
R-squared	0.086				

Robust standard errors below
*** p<0.01, ** p<0.05, * p<0.1

Notes: The dependent variable is log annual wage income. The regressions include all the same control variables as before, i.e. age, gender, tenure, months employed, firm size, dummies for the field and level of education, dummies for the sector of the firm, dummies for the firm's regional location, and year dummies.

Table 6. Returns by assignee type

Variable	FE	FD
Patents assigned to individuals		
PATENTS	-0.076*	-0.075**
	0.042	0.038
PATENTS (t-1)	-0.127**	-0.150***
	0.064	0.058
PATENTS (t-2)	-0.057	-0.090
	0.080	0.083
PATENTS (t-3)	0.109	0.078
	0.121	0.103
PATENTS (t-4)	0.039	-0.022
	0.103	0.080
PATENTS (t-5)	0.204	0.158*
	0.125	0.087
PATENTS (t-6)	0.306**	0.314
	0.149	0.201
Patents assigned to firms		
PATENTS	0.0251*	0.0285*
	0.015	0.015
PATENTS (t-1)	-0.003	0.007
	0.022	0.023
PATENTS (t-2)	-0.023	-0.024
	0.023	0.025
PATENTS (t-3)	0.011	0.006
	0.020	0.022
PATENTS (t-4)	0.043**	0.043*
	0.022	0.022
PATENTS (t-5)	0.051**	0.043**
	0.021	0.020
PATENTS (t-6)	0.040**	0.043**
	0.016	0.017
AGE	0.204***	
	0.046	
AGE^2	-0.0017***	-0.0016***
	0.0005	0.0006
TENURE	0.0082***	0.0070***
	0.002	0.002
MONTHS	0.0064*	0.004
	0.004	0.004
FIRM SIZE	0.0042***	0.0035***
	0.0009	0.0010
CONSTANT	4.561***	0.187***
	1.18	0.06
Observations	4938	3126
Individuals	1789	1639
R-squared	0.079	0.04

Robust standard errors below
*** p<0.01, ** p<0.05, * p<0.1

Notes: The dependent variable is log annual wage income. All regressions include dummies for the field and level of education, dummies for the sector of the firm, dummies for the firm's regional location, and year dummies. FE are the results from using the within (fixed effects) estimator, and FD are the results from the first-differenced regressions.