Inventors' Returns to Patents

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Abstract

We estimate individual returns to patents using a unique longitudinal dataset on patents and earnings, following individuals and firms for 20 years (1987-2006). We find that inventors' wages steadily increase before patent applications are submitted to the EPO, peak in the year preceding their filing, and then decrease again. We take the fact that earnings peak at *t-1* instead of at *t* as a bureaucratic delay between the time the invention really takes place and the time when the EPO registers the application. Our evidence supports the theories predicting that firms pay a yearly premium up to the time an invention is completed, probably to retain their key workers until they are able to submit the patent application to the EPO. We also find that inventors who are eventually granted a patent receive a greater wage increase than those who are not.

JEL classification: O31, J31.

Keywords: Patents; Wages; Incentives; Inventors; Performance pay; Return.

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1 Introduction

While the benefits firms derive from patenting have been analyzed in the literature (see, for instance, Hall, Jaffe, and Trajtenberg (2000); Geroski, Machin and Van Reenen (1993); Balasubramanian and Sivadasan, 2011)), very little work exists on the incentives for workers to invent. Understanding inventors' incentives may be important to increase firms' innovation rates and, ultimately, the micro-foundations of countries' technological progress. Although monetary incentives may not be the primary source of motivation for pure researchers, who are perhaps spurred more by a passion for research or a search for fame, wage premia serve to acknowledge good work and may motivate other types of inventors (some patents are for on-the-job improvements made by engineers or blue-collar workers). Nevertheless, in most countries employees are requested to cede all the property rights of their inventions to their employers, so patenting does not necessarily provide inventors with monetary compensation. However, informal talks with some inventors and the (scant) existing empirical evidence indicate that on average workers do obtain a premium after an invention. On the basis of a sample of almost 600 firms observed over 6 years, Van Reenen (1996) finds that 4 years after commercialization a (major) innovation raises firms' aggregate wages by 2 percent. Toivanen and Väänänen (forthcoming) estimate inventors' returns to patents by using individual data on almost $2,000$ Finnish inventors whose inventions were patented in the U.S. over a period of 9 years $(1991 - 1999)$. They show that inventors obtain a $1 - 2$ percent premium in the year the firm is granted a patent and a $3 - 4$ percent wage increase in the fourth year after the patent is granted, although in Finland the existence of a premium is expected, as firms are legally obliged to reward their employees when they take out a patent.

In this paper we estimate individual returns to patents by using a unique longitudinal dataset on patents and earnings, following individuals and firms for 20 years $(1987 - 2006)$. In particular, we build a new concordance between the European Patent Office (EPO) database on patents (Patstat) and the Italian employer-employee matched dataset on individual wages from the Italian Social Security Institute (INPS). To the best of our knowledge we are the first to link the EPO patent data to individual inventors' wages and demographic and job characteristics. We are able to match 65 percent of all the inventors found by INPS in their employee archives; that is, 40 percent of the universe of inventors employed in an Italian firm who contributed to at least one patent application submitted to the EPO between 1987 and 2006.

The length of our panel allows us to study the structure of inventors' earnings. Accordingly, adding to Toivanen's and Väänänen's work, which is based on a short panel dataset, we are able to verify empirically whether inventors obtain a one-off bonus at the time of the submission of patent applications, as efficiency wage theories would predict, or a permanent wage increase, in line with career concern studies. Our data also has the advantage of being unaffected by systematic measurement errors, because the INPS dataset is an administrative one (see Abowd and Card, 1989). Moreover, in contrast to wages from other employer-employee matched datasets, INPS earnings are not top-coded.

We estimate individual returns to patents with a Mincerian wage function augmented with patent applications on the inventors' sample. We always run fixed-effect estimations controlling for individual fixed effects, so our estimates are consistent even in the presence of individual unobservable time-invariant characteristics. Our results indicate that inventors' wages steadily increase before patent applications are submitted to the EPO, peak in the year preceding their filing, and then decrease again. We take the fact that earnings peak at *t-1* instead of at t as a bureaucratic delay between the time the invention really takes place and the time when the EPO registers the application. Our evidence supports the theories predicting that firms pay a yearly premium up to the time an invention is completed, probably to retain their key workers until they are able to submit the patent application to the EPO. We also test whether there is a difference between the applications that are eventually granted and those that are not. Although the pattern is similar in the two cases, the inventors who actually obtain a grant obtain a greater wage increase than those who do not.

The paper is structured as follows. The next section presents the related literature, Section 3 the dataset, the variables and the descriptive statistics. Section 4 reports the empirical model and discusses the estimation results. Finally, the last section concludes.

2 Related literature

While the majority of the literature analyzes the impact of patents at the national, sectoral, or firm-level, very few studies examine the benefits accruing to inventors. At the country level, Eaton and Kortum (1999) find that patents raise R&D and growth. Studies at the firm level show that patents increase market value (Griliches, Pakes and Hall (1986) and Hall, Jaffe, and Trajtenberg, 2000), profitability (Geroski, Machin and Van Reenen, 1993), R&D (Arora, Ceccagnoli, and Cohen, 2008), and are positively correlated to companies' size, skill and capital intensity, labor productivity and TFP (Balasubramanian and Sivadasan, 2011). In contrast, Boldrin and Levine (2013) argue that the evidence in favor of any effect of patents on innovation or productivity is not conclusive.

The scantness of data on inventors' earnings has certainly limited the amount of research on returns to patents. Indeed, most studies link patent data to information at the firm level. Thus, using aggregate earnings data on 600 companies, Van Reenen (1996) finds that firms' average wages increase by 2 percent 4 years after they commercialize a major innovation. Linking compensation survey data to the NBER patent information from the US Patent and Trademark Office (USPTO), Lerner and Wulf (2007) obtain that offering stock options to corporate R&D heads has a positive effect on firm's patent citations, awards and original patents. Toivanen and Väänänen (forthcoming) link a Finnish employer-employee matched dataset to the NBER patent grant data over the period $1991-1999$. They show that, after controlling for individual fixed-effects, inventors obtain a $1-2$ percent premium in the year the firm is granted a patent and an average $3-4$ percent wage increase four years after.

From a theoretical point of view it is not obvious that patents produce any individual return, since in most countries applicant firms retain all the inventions' property rights and are not legally obliged to reward their employees for patenting (except for "occasional inventions"; see Sabbatini, 2011).[1] Thus, why firms choose to reward inventors even if they do not have to is an interesting issue, hardly examined before.

The agency literature is a good framework to analyze individuals' incentives to patent: firms

[1]Note that this is not the case in Finland, where firms are legally obliged to reward the employees who take out a patent. Thus, Toivanen's and Väänänen's (forthcoming) main issue is the quantification of the premium paid rather than analyzing whether a premium exists.

(principals) have to decide whether to hire potential inventors (agents') without knowing their ability and/or effort, and inventors have to choose a level of research activity without knowing whether they will be successful. In this context, the existence of returns to patents can be explained by three alternative theoretical frameworks: career concerns, relational incentives and intrinsic motivation.

a) Career concerns. When inventors take out a patent they reveal their true ability to both current employers and rival firms, and thus increase the value of their outside options. Because outside offers matter, inventors would have an incentive to exert a positive effort even without explicit compensation schemes based on performance. However, since the cost of losing an inventor could be particularly high to the firm, employers might offer quasi-rents to retain inventors in their company, in which case returns to patents would reflect current employers' attempt to avoid poaching from rivals.[2] In this framework, patent compensation would be timely and would permanently shift inventors' wage curve upwards (in the form of either a permanent bonus or a promotion).

b) Relational incentives. Firms might find it profitable to share the rent from patents with inventors to raise their effort, their loyalty, the value of their firm-specific job, to reduce their turnover, or to attract the best workers.[3] In a relational contract context (see Malcomson (2013) for a review) firms may be willing to share their expected surplus from patents to avoid that inventors perceive their lack of benefits from patenting as unfair and will consequently reduce their future creative effort.[4] In repeated-game models firms develop a reputation for rewarding inventors, and employees invest in looking for innovations with that expectation. Firms do not renege the expected reward because otherwise they would lose credibility and from then on workers would not innovate anymore. The literature on efficiency wages (see Prendergast (1999) for a review) shows that employees tend to exert more effort when their pay is more closely related to their performance,

[2]In the absence of firm competition there is no enforcement mechanism guaranteeing that employers would actually adjust wages once they change their beliefs on inventors' true productivity.

[3]According to Petra (2013), in 1474 the Venetian Republic put in place one of the first systems in history to give inventors and firms exclusive rights on their invention. Its main aim was attracting the most skilled artisans.

[4]In Fehr's and Schmidt's (1999) model the presence of inequity-averse workers induces (selfish) firms to pay efficiency wages in the fear that otherwise workers would reduce their effort. In Rabin's (1993) approach firms feel the obligation to reward employees for their loyalty for a question of reciprocity, to avoid that without a compensation workers feel mistreated and sabotage them.

and that effort increases with the size of the prize.[5] Often workers' performance is difficult to observe, but inventors's productivity can easily be measured in terms of patent grants. Thus, in a relational incentive framework employers may adopt contracts such as pay-for-performance schemes, providing inventors with temporary bonuses at the time of patent application and/or grant. Since attempting to innovate necessarily involves failures, Manso (2011) argues that the compensation schemes best tailored at motivating innovation should tolerate early failing and reward long-term success. In this light, standard pay-for-performance schemes punishing failures with low rewards and/or termination may in fact discourage innovation. Ederer and Manso (2012) suggest that the compensation schemes best aimed at fostering innovation should be long-term, should provide job security and timely feedback on performance, and should also be path dependent (i.e. inventors doing well initially but poorly later should earn less than those who perform badly initially but well later).

c) Intrinsic motivation. Inventors may invest in research activity just because they enjoy it. According to some non-economic literature (see Prendergast (1999) for a review and Kreps (1997) for a critique to this approach), offering workers a monetary premium to carry out research activity would in fact *reduce* their intrinsic enjoyment of the task, and thus lower their propensity to patent. According to this view, pay-for-performance contracts inhibit creativity, because monetary incentives reduce employees' intrinsic desire to carry out certain activities. In this framework, we should observe no wage variation after a patent submission or grant.

Contracts on patents could be explicitly set or discretionary, but they would be firm-specific, as for the Italian law companies might choose not to reward inventions. Since our data do not provide information on contracts we will be only able to infer which is the prevailing contract on the average of patenting firms. In Section 4 we will verify empirically which of the alternative explanations of the existence of returns to patents is consistent with our data.

[5] Lazear (2000) finds both that a switch from hourly wages to piece-rate pay raises average productivity of labor and that firms share the productivity gains with their workforce.

3 The data and descriptive statistics

We link the employer-employee matched data from the Italian Social Security Institute (Istituto Nazionale di Previdenza Sociale, INPS) to Patstat, the EPO Worldwide Patent Statistical Database.

INPS is an administrative dataset[6] following private-sector workers and firms over time. The information on employees comprises: age, gender, municipality of residence and municipality of birth, work status (blue collar; white collar; manager; other), type of contract (full-time versus part-time) and gross yearly earnings. In contrast to similar databases in other countries (e.g. Germany, France) INPS wages are not top-coded. The information on firms includes: average gross yearly earnings, average number of employees, industry, plant location (at the municipality level), date of plant opening and closure.

Patstat contains the universe of patent applications and grants presented at the EPO by any Italian firm since 1978 (when Italian companies started applying at the EPO). The database provides a detailed description of each patent submission, including its title, abstract and technological field, the name and address of residence of all its inventors and applicants (i.e. the firms submitting a patent application and retaining the relative property rights), the dates of application filing, publication and grant obtainment.

Like the USPTO dataset also Patstat lacks of a firm identifier. Thus, we did a large matching-name work to link Patstat companies and inventors to INPS firms and employees. We first attributed VAT codes to Patstat firms on the basis of the company name and location. Subsequently INPS linked Patstat companies to all possible INPS firms that either had the same VAT identifier or the same name and municipality of residence. At the same time INPS searched for all the inventor names recorded in their registry of employees. Finally, we matched Patstat inventors to the INPS employees having the same name and the same employer at the time of the patent submission. Thus, our matching procedure is more precise than the previous ones that used to match patenting companies to other sources of firm data only on the basis of companies' names and location (e.g. the NBER patent data), because we were also able to exploit the information on employees (see Thoma et al. (2010) for an extensive discussion on how to combine large patent datasets at the

[6]Like all administrative data it is not affected by systematic measurement errors (see Abowd and Card, 1989).

firm level).

Our employer-employee matched dataset covers the years 1987-2009. INPS provided us with all the patenting firms that they were able to match to their records and a sample of non-patenting firms distributed across the other Italian regions, for a total of 9,748 firms (19,022 plants in the whole period). Moreover, we have individual-level information on all the workers employed in any of these firms and the full work history of the employees working in a patenting firm (even if they moved from / to a non-patenting firm). More specifically, we have 3,658 patenting firms and 4,648 patenting establishments, for a total of 13,780 inventors and almost 3,500,000 co-workers.

The EPO releases a new version of Patstat twice a year, but it takes about three years to update its records, thus the most recent data are always incomplete. For this reason we dropped all the patent applications filed in the last three available years (2007-2009, as our Patstat version is April 2009). In 2009 the stock of Italian firms' applications at the EPO was above 52,000. Besides dropping the 4,523 applications filed after 2007 (of which only 157 had already been granted), we also excluded those presented before 1987 (that is, 5,342, of which 2,788 granted) because we lack of INPS data for that period. We also drop about 130 patent submissions filed exclusively by universities, because INPS does not generally collect data on academics and we want to avoid a selection bias.[7] After excluding the submissions missing relevant information (e.g. applicant or inventor names, application dates, etc.) our dataset comprises 90,630 firm-inventor-patent records, for a total of about 12,000 firms, 33,829 inventors, and 42,691 patent submissions.

INPS was able to find 64 per cent of the inventors' names in their registry of employees. The 12,275 unmatchiable inventors are either are non-employees (e.g. consultants, self-employed or non-formally employed) or are employed in an institution not registered with INPS, most likely in the public sector.[8] We were able to match 65 per cent of the remaining 21,554 inventors, working in 3,658 different firms. Overall, we have an unbalanced panel of almost 165,000 observations (9,000 inventors per year, on average). When we include all the inventors' co-workers our sample size rises to almost 25,000,000 observations: inventors are 0.7 percent of the patenting firms' workforce.

[7] We keep the applications with collaborations between firms and universities.

[8] In Italy there are two main social security institutions for employees: INPS and INPDAP. The former deals with most of the private sector and the latter with most of the public sector (including universities).

As known, the distribution of patents per inventor is very skewed to the left. The statistics based on Patstat show that almost 15 percent of the inventors contributes to just one patent submission in their life, one-fourth to two; only 2 percent of the inventors applies more than 30 times (Figure 1). The distribution of granted patents is even more skewed, with 17 percent of the inventors not obtaining any in our observational period, and almost one-fifth being granted just one (Figure 2). The average number of years for an application to be granted is about 4.4 (see Table 1).

Table 2 shows the distribution of patent applications by sector. As expected, patents are mostly concentrated in the industrial sector, especially in terms of inventors (96 percent of total inventors are employed in industry). The public sector accounts for 1.6 percent of submissions, the retail sector for 1.8 percent; handcraft industries, which tend to be smaller and more traditional than the others, hardly apply. Geographically, most of the applications are concentrated in the North of Italy; just the Lombardy region accounts for 40 percent of total submissions (see Table 3 and Figure 3).

Table 4 shows the descriptive statistics for the whole sample, the sub-sample of inventors and a 10 percent random sample of their co-workers. The last column reports the p-values of the t-tests of equality in means between columns (4.2) and (4.3). As expected, individual wages are significantly (much) higher for inventors than for non-inventors. Figure 4 reports the average gross yearly earnings for the two groups of workers (inventors' wages have been re-scaled for an easier comparison). The figure shows that inventors' wages have been more markedly increasing over time than those of the rest of the sample. From a comparison across the columns of Table 4 it is apparent that inventors tend to be older and with longer-term contracts than the rest of the workers. The inventor's sub-sample exhibits a lower share of women and blue-collar workers, and a slightly higher percentage of white-collar workers. Finally, the share of workers with a full-time contract is very similar across the inventor and the non-inventor sub-groups.

4 The empirical model and results

We estimate individual returns to patents with a Mincerian wage function (see Mincer, 1976) augmented with patents:

$$w_{it} = \sum_{k=-K}^{K} \delta_{t-k} Patent_{i,t-k} + X_{it}'\beta + \alpha_i + \gamma_t + \epsilon_{it}, \quad (1)$$

where w_{it} is the gross yearly income of employee i in year t (including social security contributions, taxes, overtime work, Christmas bonuses), X_{it} is a vector of individual observable characteristics, including a quadratic form of age, work status (blue collar, white collar or manager), and type of contract (full-time or part-time); α_i are worker fixed effects; γ_t are year dummies; and ϵ_{it} is an error component with zero mean.

All the estimates presented in this paper exploit the longitudinal dimension of the dataset, using workers' fixed effects to have consistent estimates even in the presence of unobservable individual time-invariant characteristics, such as personal ability, intelligence, or, education (to the extent that most workers do not improve their education after entering the labor market).[9] Errors are always clustered both at the individual and at the firm level (Cameron, Gelbach and Miller, 2011).

The main objective of this paper is to test whether employees obtain a premium when they contribute to a patent submission, and whether this takes the form of a one-off bonus at the time of invention, in line with the relational incentives theoretical framework, or whether it permanently increases wages, as career concerns theories would predict (see Section 2). Consistently with this aim we augment the set of co-variates with *Patent*, a proxy of innovation. Following a large body of literature we measure innovation with patent submissions (see, for instance, Griliches, 1990). In contrast to Toivanen and Väänänen (forthcoming) we use submitted rather than granted patents for two main reasons. First, because the former are a better and more timely indicator of whether individuals are engaged in research activity (Lotti and Schivardi, 2005). Second, because using grants instead of submissions increases the likelihood that the patenting inventor moved to another

[9] Although we recognize that part of these unobservable characteristics may in fact be time-varying, we are confident that our approach eliminates most of this pitfall.

firm (the EPO takes more than 4 years, on average, to grant a patent; see Table 1), which would bias the results. In our main model we define $Patent_{i,t}$ as a dummy variable equal to one if the employee contributed to a patent submitted at time t. Nevertheless, since grants may provide a better-quality signal on inventors' ability than applications, we also split submitted patents into those that have eventually been granted in our observational period and those that have not. Since we aim at discerning whether the premium is one-off or lasting, in all specifications we include 19 forward-lags and 19 backward lags of the patent variable ($Patent_{t-s}$ and $Patent_{t+s}$, with s=0,1, ...19), independently of how $Patent_{i,t}$ has been defined.

Table 5 and Table 6 report the results. In Table 5 $Patent_{i,t}$ is a dummy variable equal to 1 if the individual contributed to a patent application in the current year. We always include its nineteen forward and backward-lags and normalize the first lead (*t-1*) to zero, so that, all else being equal, the marginal returns to patents at time t with respect to *t-1* is just the coefficient on earnings at t. In all specifications we control for the number of co-authors of the patent application, as informal talks with some inventors suggest that firms may pay a fixed premium per patent submission to be split among all co-authors. Finally, we add the number of patent applications that inventors submit each year, to test whether the employees who contribute to more than one per year obtain a higher premium than the others.

We test six specifications, progressively adding the observable co-variates. In the first column of Table 5 we just control for the patent proxies reported above and the individual fixed effects. In the second specification (5.2) we add the time dummies, in the third one we include a quadratic form of inventor's age. In the fourth column we control for work status (white collar, manager, other, versus blue collar) and in specification (5.5) we add some characteristics of the worker's plant: the region and the sector (services, the public sector, handcraft, retail, agriculture - industry is the omitted category). Finally, in column (5.6), which is our benchmark, we also include firm's size (the number of employees and the number of plants).

Results show that after controlling for individuals' age, inventors' wages peak at time *t-1* (see Figure 5). In particular, inventors' earnings at *t-1* are 3.4 percent higher than at *t-2*; the year after they fall by 1.7 percent (column (5.6)). The time lag between t and *t-1* could simply be due to the fact that the EPO files applications with a certain delay. Indeed, when employees complete an invention, they first submit it to the firm's legal office, which takes a few months before deciding whether the invention is worth applying at the EPO; in case of a positive response, the firm submits it and then the EPO registers the application. We expect employers to reward inventors when they complete the invention, which is likely to be before the filing date. As Figure 5 shows, earnings steadily increase before submission. Indeed, we reject the null hypothesis that $Y_{i,t}$=$Y_{i,t-1}$=...$Y_{i,t-s}$. We interpret this result as firms having inside information on their inventors' research progress: employers pay inventors a yearly premium to avoid that they leave before the patent is completed. After submission, earnings drop (we always reject the null hypothesis that $Y_{i,t}$=$Y_{i,t+1}$=...$Y_{i,t+s}$), but they never return to their previous level, as the wage curve is not symmetrical: s years before an invention wages are lower than s years after (i.e. the patent coefficients s years after an invention are higher than those s years before the invention). A formal t-test always rejects the null hypothesis that wages at time t-s are equal to wages at time t+s (for any s). Finally, the variables number of coauthors and number of applications per year are never significant.

In Table 6 we split patent submissions into the applications that have been granted and those that have not. Column (6.1) reports the results on the whole sample, corresponding to our benchmark specification of Table 5 (5.6). The pattern is similar to the benchmark's, although the inventors who contribute to a patent application that is eventually granted experience a higher wage increase than those who do not obtain a grant (Figure 6 (a) and (b)).

The results are robust to restrict the sample to: a) industry (the most patent-intensive sector; column (6.2)); b) the North of Italy (the most patent-intensive area of the country; specification (6.3)); c) the Center of Italy (column (6.4)) and the industrial sector in the North (specification (6.5)).

5 Conclusions

This paper analyzes the impact of patents on inventors' wages. We use a longitudinal dataset on patents and earnings, following individuals and firms for 20 years (1987-2006). We test the validity of various theories, verifying whether a patent application premium exists, and if so, whether it is lasting or temporary.

Our results show the presence of an inversely U-shaped patent wage premium after conditioning on observable characteristics and individual unobservable heterogeneity. Thus, our estimates are unbiased and consistent even in the presence of constant omitted variables (e.g., ability, intelligence and possibly education). In particular, our estimates show that inventors' wages steadily increase before patent applications are submitted to the EPO, peak in the year preceding their filing, and then decrease again. We take the fact that earnings peak at *t-1* instead of at t as a bureaucratic delay between the time the invention really takes place and the time when the EPO registers the application. Our evidence supports the theories predicting that firms pay a yearly premium up to the time the invention is completed, probably to retain their key workers until they are able to submit the patent application to the EPO. We also find that the inventors who are eventually granted a patent receive a greater wage increase than those who are not. Finally, we control for the number of coauthors and for the number of applications per year, although they seem to have a low explicative power.

Firms' motivation for rewarding inventors is beyond the scope of this paper. However, one possible explanation is that by rewarding inventors companies benefit from productivity increases. This hypothesis is consistent with Jones's and Kato's (1995) finding that offering employees a bonus 10 percent higher than in competitor firms raises the company's productivity the year after by 1 percent.

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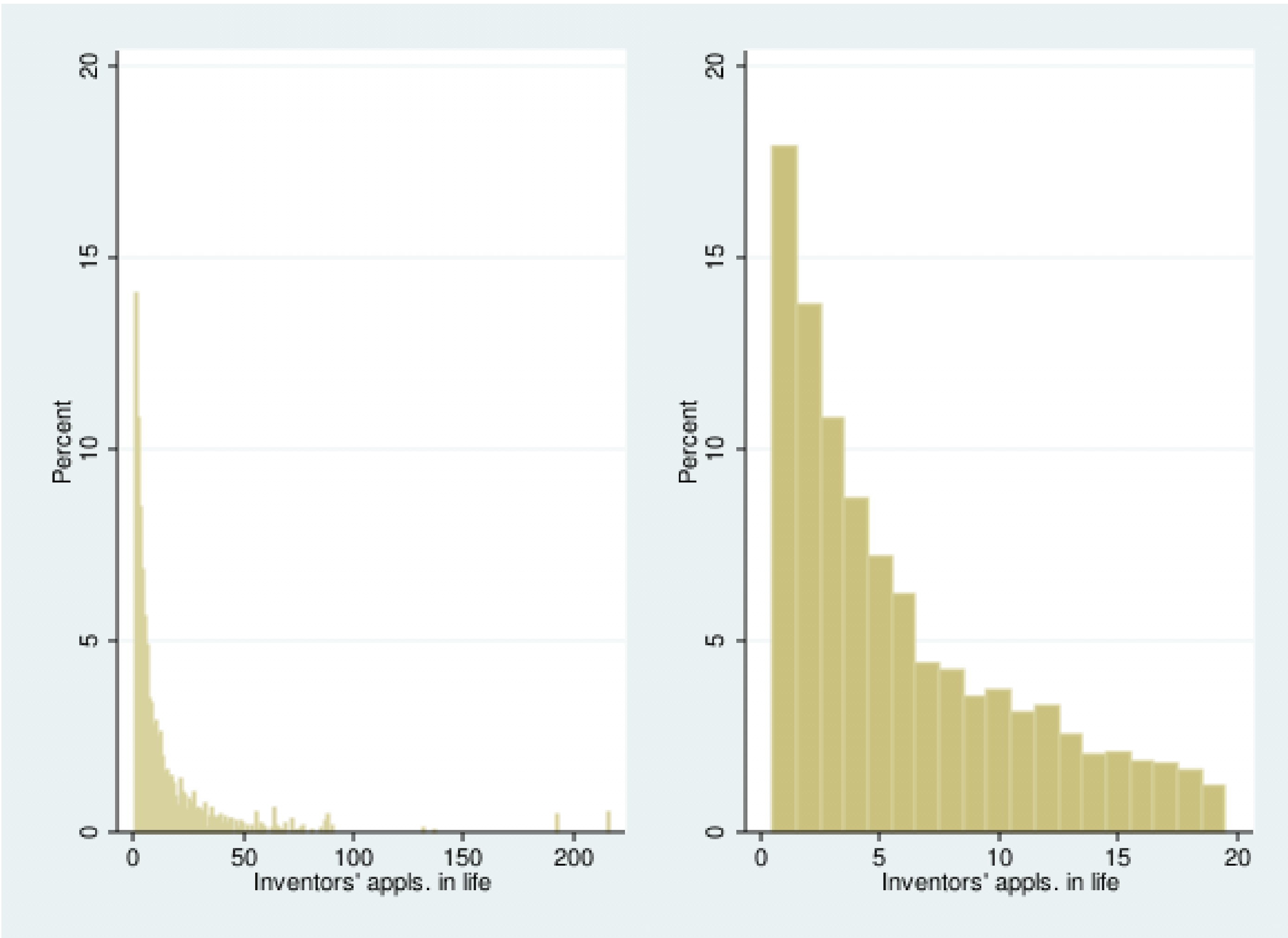
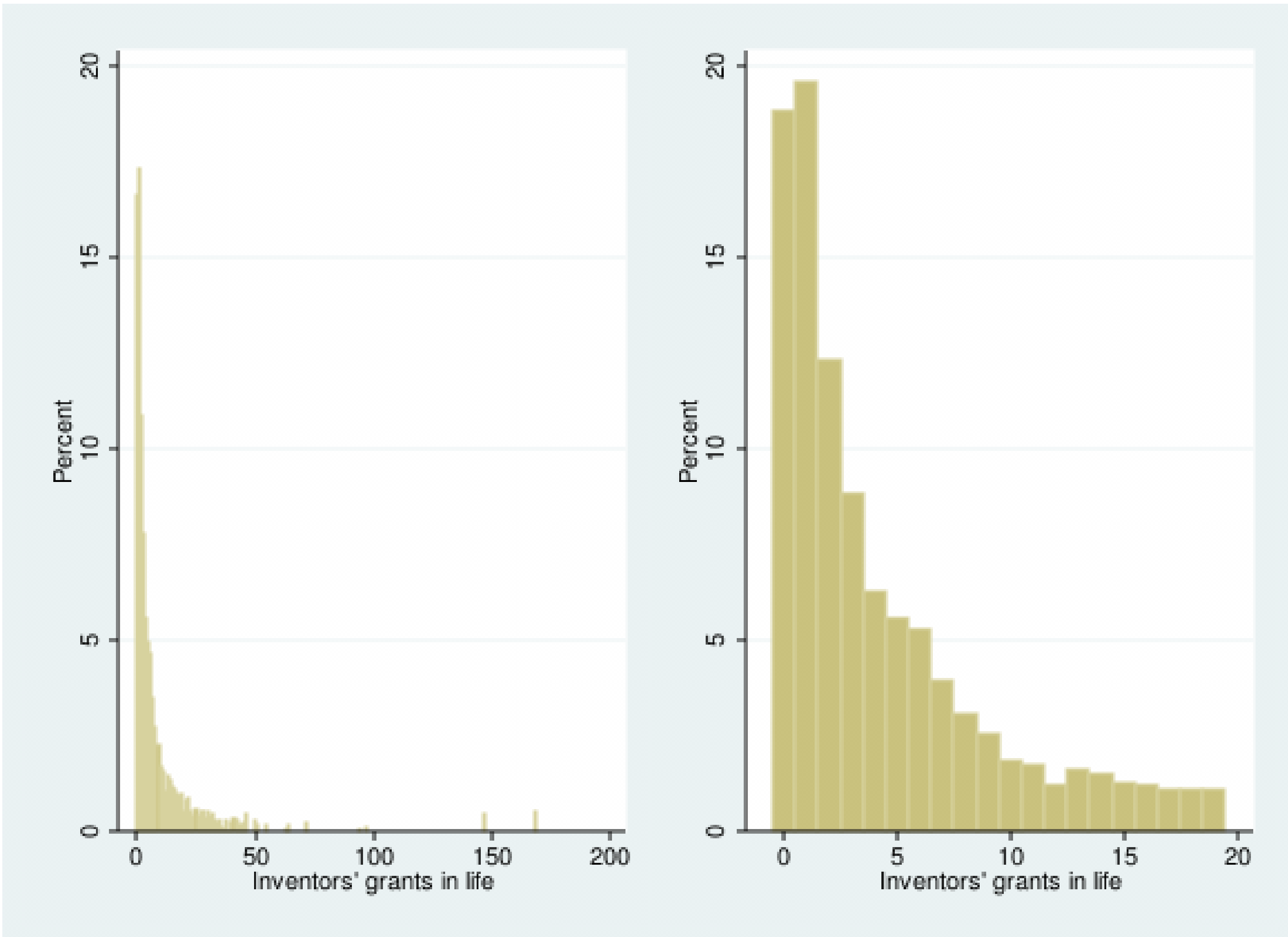
Figure 1: Patent applications per inventor



Note: (a) full sample; (b) sample of inventors with less than 20 applications.

Figure 2: Patent grants per inventor



Note: (a) full sample; (b) sample of inventors with less than 20 grants.

Table 1: Number of years from application to grant

	Applications			Years to grant			
Year	Total	Granted	Not yet granted	Min	Mean	Median	Max
1987	791	585	206	2	4.8461538	5	16
1988	850	617	233	2	4.560778	4	9
1989	979	661	318	2	4.5037821	4	16
1990	1198	832	366	2	4.4975962	4	14
1991	1111	756	355	2	4.3677249	4	11
1992	1344	839	505	2	4.2967819	4	14
1993	1307	968	339	1	4.5320248	4	14
1994	1256	905	351	1	4.7016575	4	13
1995	1401	1034	367	1	5.0290135	5	14
1996	1572	1177	395	1	5.1690739	5	12
1997	1698	1163	535	1	5.2803095	5	12
1998	1824	1174	650	1	5.2614991	5	11
1999	1800	1162	638	2	5.0886403	5	10
2000	2068	1267	801	2	4.7979479	4	9
2001	2373	1365	1008	1	4.3941392	4	8
2002	2785	1530	1255	1	3.9830065	4	7
2003	3035	1434	1601	1	3.8640167	4	6
2004	3084	1339	1745	1	3.2755788	3	5
2005	3025	902	2123	1	2.9789357	3	4
2006	3195	613	2582	1	2.4013051	2	3

Table 2: Distribution of patent applications by sector

Sector	Applications (2.1)	Inventors (2.2)	Applicants (2.3)
Industry	95.8	96.1	94.3
Services	0.4	0.2	0.1
Public	1.6	2.0	0.6
Handcraft	0.3	0.1	0.6
Agriculture and Fishing	0.2	0.1	0.2
Retail	1.8	1.6	4.1
Total	100.0	100.0	100.0

Table 3: Distribution of patent applications by region

Region	Applications (3.1)	Inventors (3.2)	Applicants (3.3)
ABRUZZI	1.2	1.0	0.9
BASILICATA	0.3	0.2	0.2
CALABRIA	0.1	0.0	0.1
CAMPANIA	0.7	0.9	1.4
EMILIA-ROMAGNA	11.7	12.2	15.9
FRIULI	5.1	4.0	3.3
LAZIO	5.6	7.7	4.8
LIGURIA	2.1	2.7	2.3
LOMBARDY	40.6	37.8	34.9
MARCHE	1.9	1.8	2.7
MOLISE	0.2	0.1	0.1
PIEDMONT	15.1	16.7	13.0
PUGLIA	0.4	0.4	0.8
SARDINIA	0.2	0.0	0.1
SICILY	2.0	1.5	0.4
TRENTINO ALTO ADIGE	1.0	0.8	1.4
TUSCANY	4.6	4.8	4.5
UMBRIA	0.5	0.3	0.7
VALLE D'AOSTA	0.2	0.1	0.2
VENETO	6.6	7.0	12.5

Figure 3: Distribution of patent applications by region

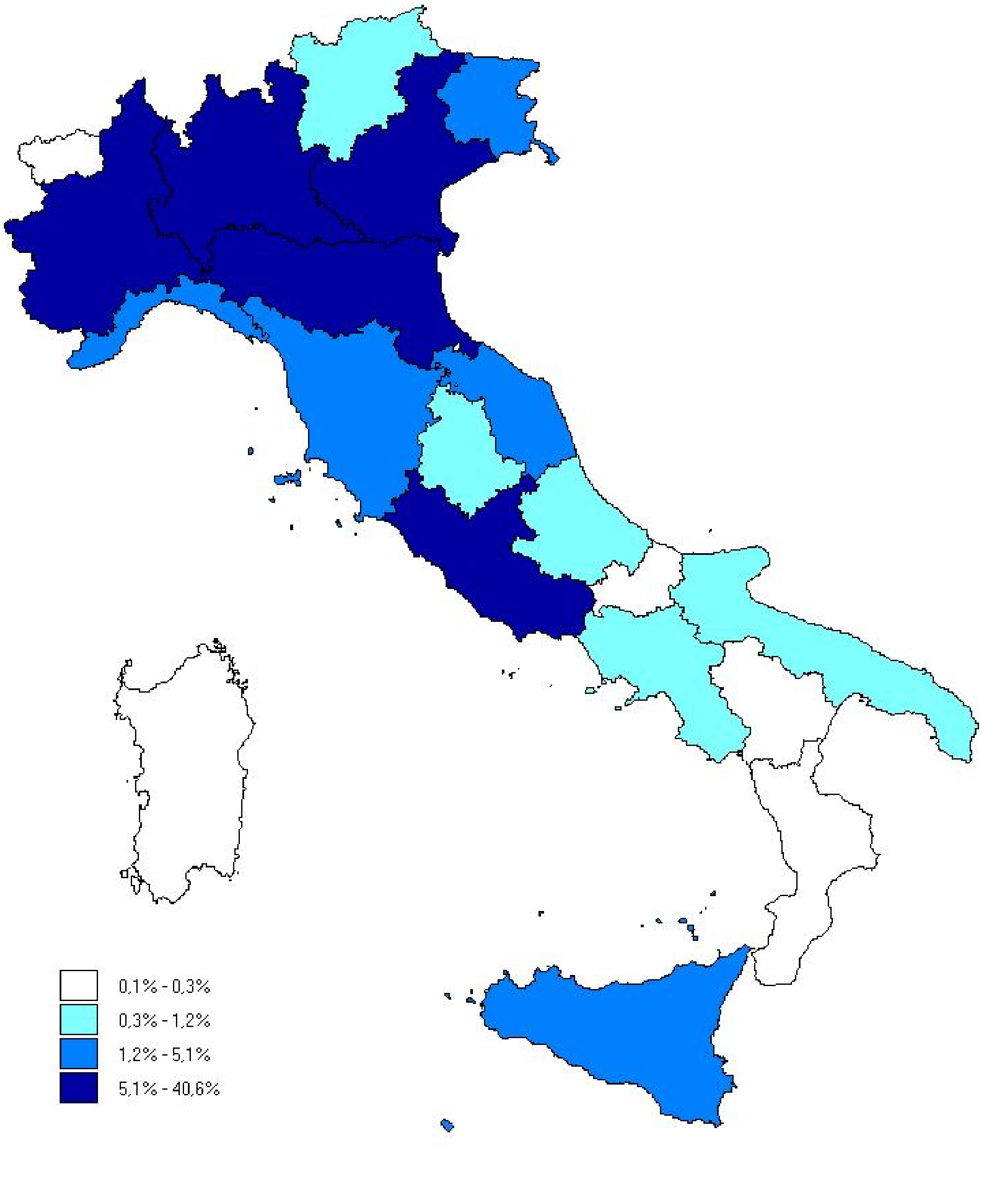


Table 4: Descriptive statistics: employees

	Whole sample (4.1)		Non-Inventors (4.2)		Inventors (4.3)		T-test (4.4)
Variable	Mean	S.D.	Mean	S.D.	P-val.		
Yearly wage	22094.0	18835.5	20712.3	16399.9	40830.6	33787.6	0.000
Female	0.2	0.4	0.2	0.4	0.1	0.3	0.000
Age	39.7	10.3	39.7	10.4	40.0	9.2	0.000
Blue collar	0.5	0.5	0.5	0.5	0.0	0.2	0.000
White collar	0.4	0.5	0.4	0.5	0.6	0.5	0.000
Manager	0.0	0.0	0.0	0.0	0.0	0.1	0.000
Other work status	0.1	0.3	0.1	0.2	0.3	0.5	0.000
Full-time	1.0	0.2	1.0	0.2	1.0	0.1	0.000
No. plants per firm	1.8	8.1					
No. workers per firm	2327140.3	4.6e+07					

T-tests for equality in means between columns (4.2) and (4.3) are reported in the last column.

Figure 4: Inventors' and non-inventors' gross yearly wages

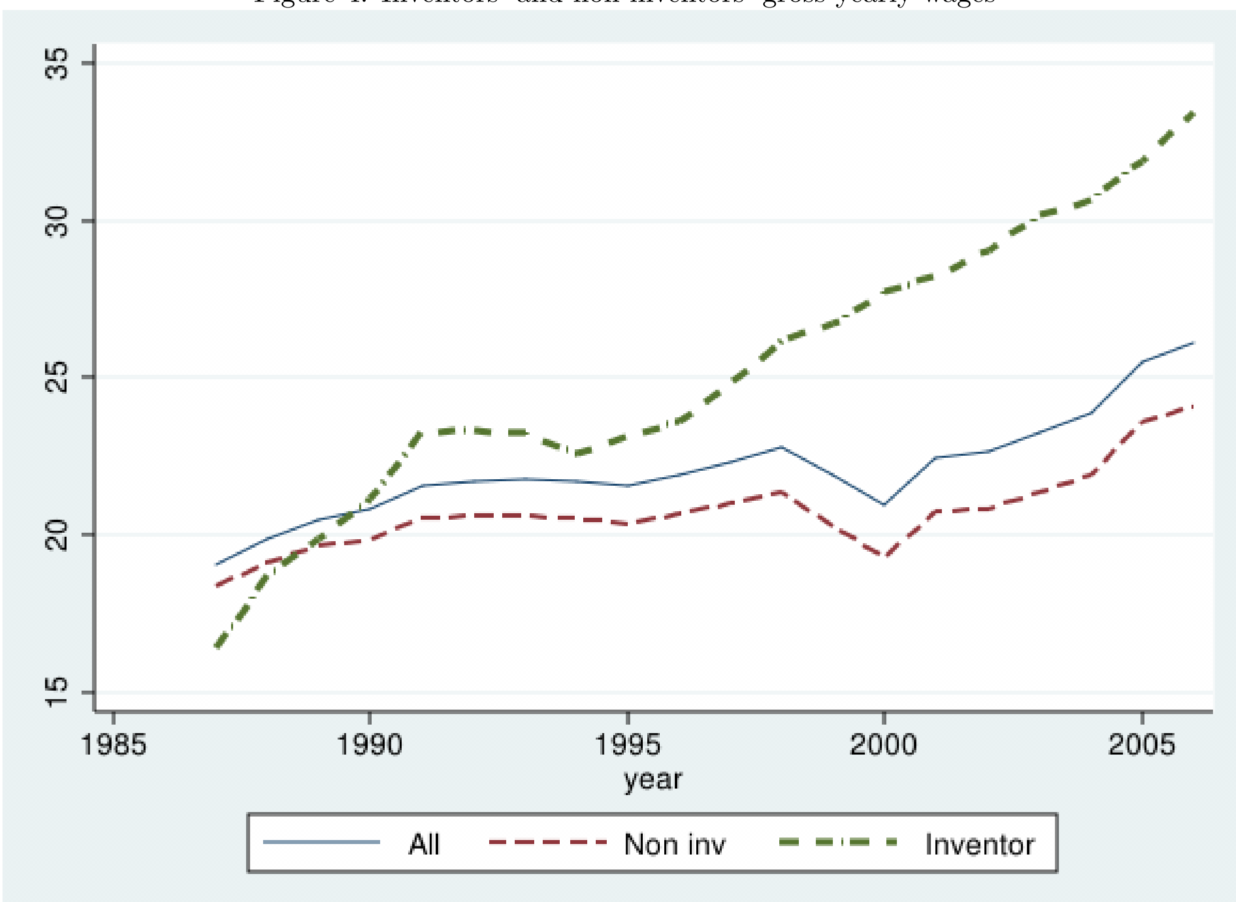


Table 5: Inventors' returns to patents

Variables	(5.1)	(5.2)	(5.3)	(5.4)	(5.5)	(5.6)
No. inventors per submis.	-0.006 ***	-0.003	-0.003	-0.003	-0.003	-0.003
Inventors' appls. per year	-0.021 ***	-0.003	0.002	0.001	0.001	0.002
Year submis.$_{t-8}$	-0.192 ***	-0.109 ***	-0.104 ***	-0.101 ***	-0.101 ***	-0.101 ***
Year submis.$_{t-7}$	-0.170 ***	-0.099 ***	-0.097 ***	-0.094 ***	-0.094 ***	-0.094 ***
Year submis.$_{t-6}$	-0.156 ***	-0.094 ***	-0.092 ***	-0.089 ***	-0.089 ***	-0.089 ***
Year submis.$_{t-5}$	-0.137 ***	-0.087 ***	-0.085 ***	-0.083 ***	-0.083 ***	-0.083 ***
Year submis.$_{t-4}$	-0.119 ***	-0.077 ***	-0.075 ***	-0.073 ***	-0.073 ***	-0.073 ***
Year submis.$_{t-3}$	-0.097 ***	-0.065 ***	-0.063 ***	-0.062 ***	-0.062 ***	-0.062 ***
Year submis.$_{t-2}$	-0.053 ***	-0.036 ***	-0.035 ***	-0.034 ***	-0.034 ***	-0.034 ***
Year submis.$_{t}$	0.048 ***	-0.010	-0.019 **	-0.018 *	-0.018 *	-0.017 *
Year submis.$_{t+1}$	-0.003	-0.034 ***	-0.035 ***	-0.034 ***	-0.034 ***	-0.034 ***
Year submis.$_{t+2}$	-0.018 ***	-0.057 ***	-0.056 ***	-0.056 ***	-0.056 ***	-0.056 ***
Year submis.$_{t+3}$	-0.024 ***	-0.068 ***	-0.065 ***	-0.065 ***	-0.064 ***	-0.064 ***
Year submis.$_{t+4}$	-0.022 ***	-0.075 ***	-0.066 ***	-0.066 ***	-0.066 ***	-0.065 ***
Year submis.$_{t+5}$	-0.029 ***	-0.084 ***	-0.071 ***	-0.071 ***	-0.071 ***	-0.071 ***
Year submis.$_{t+6}$	-0.032 ***	-0.089 ***	-0.072 ***	-0.072 ***	-0.072 ***	-0.071 ***
Year submis.$_{t+7}$	-0.025 ***	-0.088 ***	-0.064 ***	-0.064 ***	-0.064 ***	-0.063 ***
Year submis.$_{t+8}$	-0.021 **	-0.095 ***	-0.067 ***	-0.065 ***	-0.065 ***	-0.064 ***
Time dummies	NO	YES	YES	YES	YES	YES
Age	NO	NO	YES	YES	YES	YES
Job characteristics	NO	NO	NO	YES	YES	YES
Sector; Region	NO	NO	NO	NO	YES	YES
Firm size; no. plants	NO	NO	NO	NO	NO	YES
Individual-FE	YES	YES	YES	YES	YES	YES
No. obs.	163,337	163,337	163,337	163,337	163,337	163,337

Notes: The dependent variable is the yearly wage. Regressions are run on the inventors' sample and use a fixed effect estimation method. Standard errors are always clustered both at the firm and at the employee level. Patent wage premia are computed with respect to the year before submission at EPO. All specifications control for: 19 forward-lags and 19 backward lags of the patent variable (available upon request). Variables denoted with * (**) [***] indicate statistical significance at the 10 (5) [1] percent level.

Figure 5: Inventors' earnings at the time of application (Table 5, column (5.6))

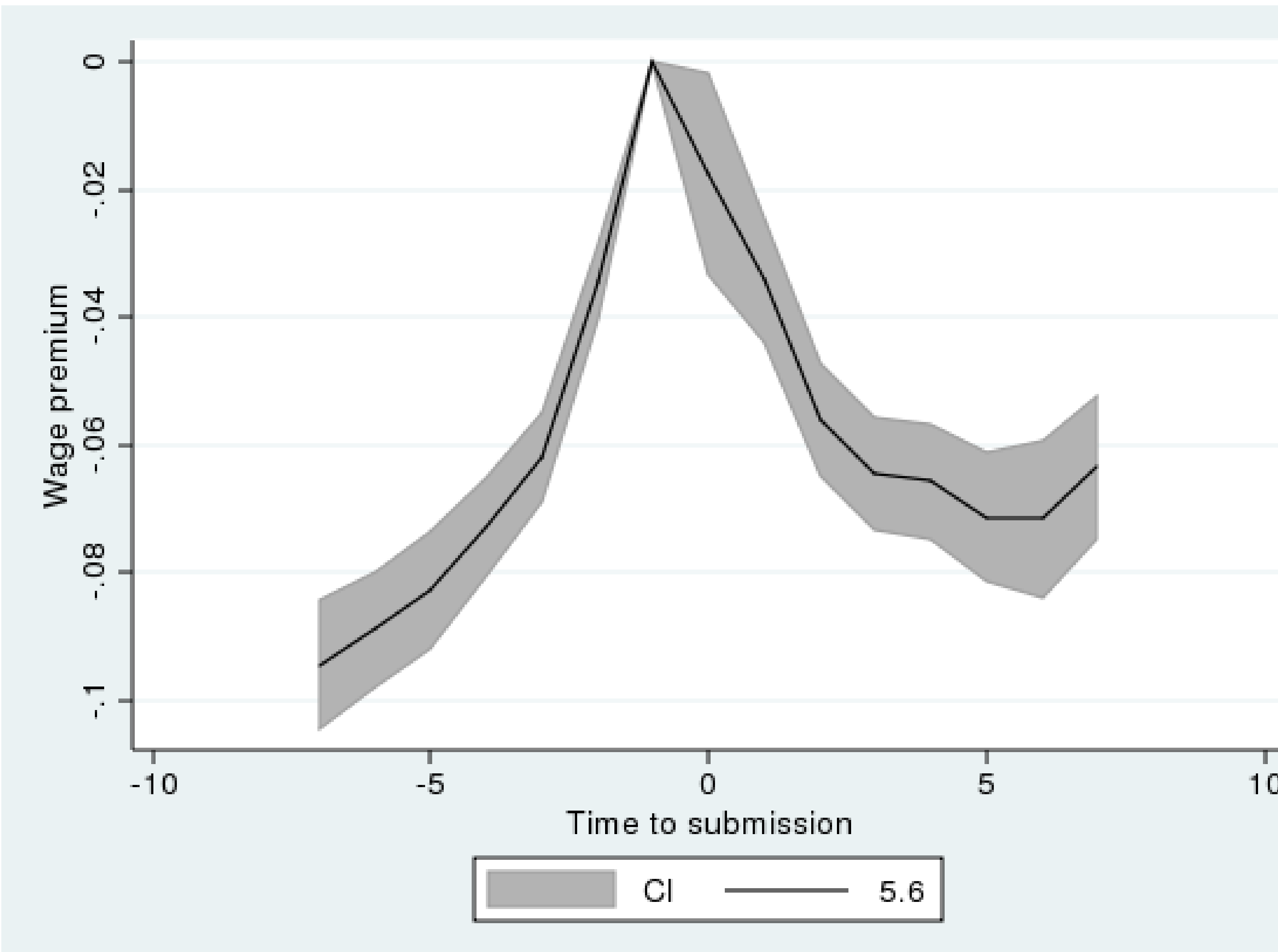


Figure 6: Inventors' earnings at the time of application (granted patents (a); non-granted patents (b))

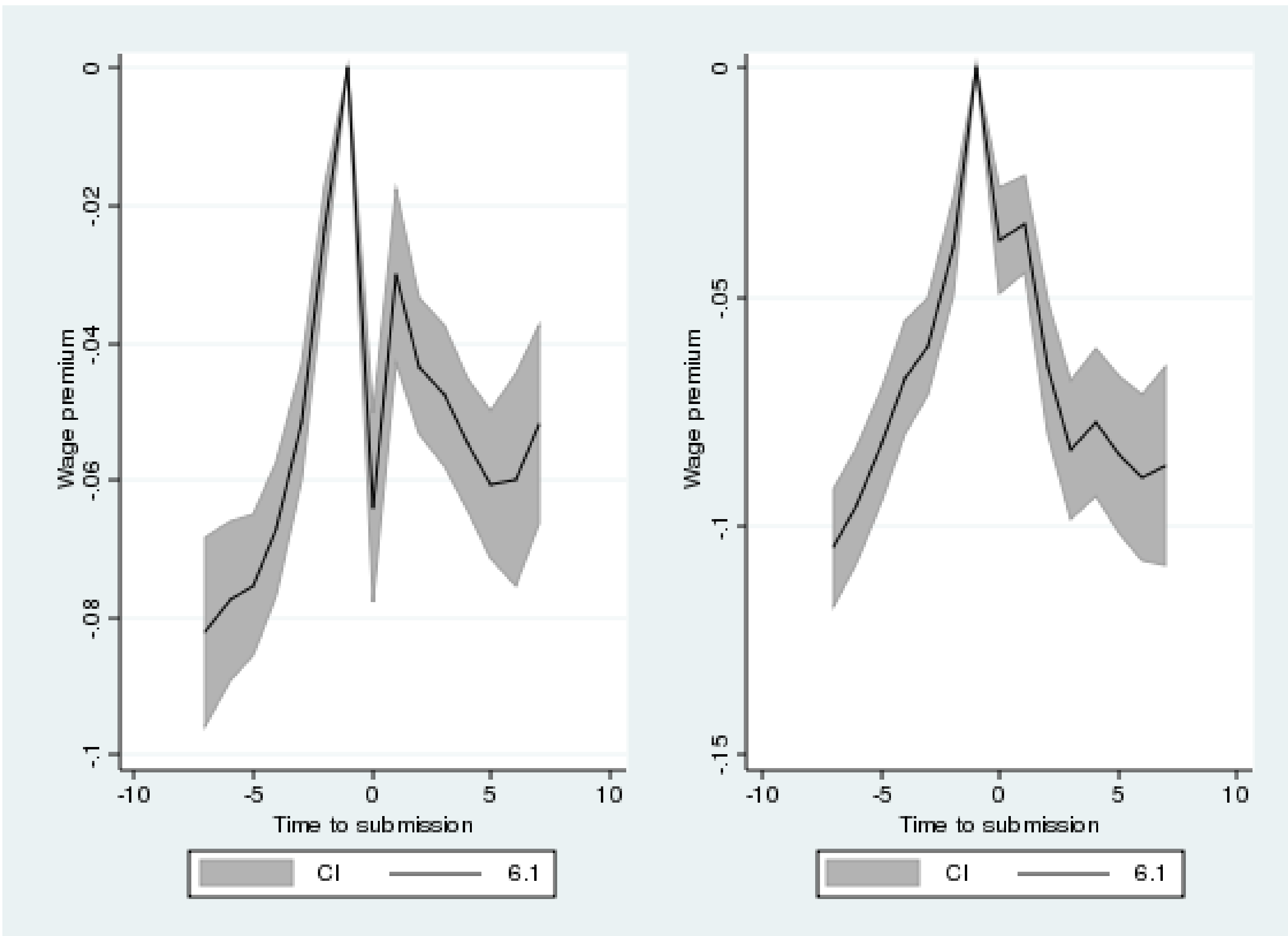


Table 6: Inventors' returns to patents (fixed effect estimation on the inventors' sample)

Variables	Whole sample (6.1)	Industry (6.2)	North (6.3)	Center (6.4)	Industry-North (6.5)
No. inventors per submis.	-0.003	-0.002	-0.003	-0.004	-0.002
Inventors' appls. per year	0.004	0.004	0.005	-0.004	0.005
(Granted application)$_{t-8}$	-0.092 ***	-0.090 ***	-0.085 ***	-0.119 ***	-0.086 ***
(Granted application)$_{t-7}$	-0.083 ***	-0.080 ***	-0.075 ***	-0.123 ***	-0.074 ***
(Granted application)$_{t-6}$	-0.079 ***	-0.078 ***	-0.075 ***	-0.103 ***	-0.075 ***
(Granted application)$_{t-5}$	-0.077 ***	-0.077 ***	-0.072 ***	-0.102 ***	-0.073 ***
(Granted application)$_{t-4}$	-0.069 ***	-0.069 ***	-0.065 ***	-0.082 ***	-0.064 ***
(Granted application)$_{t-3}$	-0.055 ***	-0.056 ***	-0.053 ***	-0.058 ***	-0.053 ***
(Granted application)$_{t-2}$	-0.026 ***	-0.026 ***	-0.026 ***	-0.020 ***	-0.026 ***
(Granted submis.)$_{t}$	-0.026 **	-0.029 ***	-0.022 **	-0.056	-0.024 **
(Granted application)$_{t+1}$	-0.034 ***	-0.034 ***	-0.034 ***	-0.039 ***	-0.034 ***
(Granted application)$_{t+2}$	-0.050 ***	-0.050 ***	-0.047 ***	-0.046 ***	-0.046 ***
(Granted application)$_{t+3}$	-0.055 ***	-0.056 ***	-0.052 ***	-0.049 ***	-0.053 ***
(Granted application)$_{t+4}$	-0.060 ***	-0.060 ***	-0.057 ***	-0.062 ***	-0.057 ***
(Granted application)$_{t+5}$	-0.066 ***	-0.067 ***	-0.069 ***	-0.035 *	-0.069 ***
(Granted application)$_{t+6}$	-0.066 ***	-0.066 ***	-0.057 ***	-0.103 ***	-0.058 ***
(Granted application)$_{t+7}$	-0.056 ***	-0.059 ***	-0.058 ***	-0.036	-0.058 ***
(Granted application)$_{t+8}$	-0.055 ***	-0.055 ***	-0.055 ***	-0.041 *	-0.053 ***
(Non-granted application)$_{t-8}$	-0.113 ***	-0.114 ***	-0.109 ***	-0.132 ***	-0.110 ***
(Non-granted application)$_{t-7}$	-0.109 ***	-0.110 ***	-0.100 ***	-0.140 ***	-0.101 ***
(Non-granted application)$_{t-6}$	-0.101 ***	-0.101 ***	-0.087 ***	-0.155 ***	-0.088 ***
(Non-granted application)$_{t-5}$	-0.090 ***	-0.091 ***	-0.083 ***	-0.118 ***	-0.085 ***
(Non-granted application)$_{t-4}$	-0.077 ***	-0.079 ***	-0.075 ***	-0.078 ***	-0.076 ***
(Non-granted application)$_{t-3}$	-0.070 ***	-0.072 ***	-0.071 ***	-0.055 ***	-0.072 ***
(Non-granted application)$_{t-2}$	-0.044 ***	-0.045 ***	-0.045 ***	-0.031 ***	-0.045 ***
(Non-granted submis.)$_{t}$	-0.016 *	-0.018 **	-0.017 *	-0.014	-0.018 *
(Non-granted submis.)$_{t+1}$	-0.036 ***	-0.039 ***	-0.035 ***	-0.040 **	-0.037 ***
(Non-granted submis.)$_{t+2}$	-0.068 ***	-0.072 ***	-0.068 ***	-0.061 ***	-0.070 ***
(Non-granted submis.)$_{t+3}$	-0.086 ***	-0.086 ***	-0.081 ***	-0.100 ***	-0.081 ***
(Non-granted submis.)$_{t+4}$	-0.080 ***	-0.079 ***	-0.069 ***	-0.128 ***	-0.067 ***
(Non-granted submis.)$_{t+5}$	-0.086 ***	-0.087 ***	-0.084 ***	-0.091 ***	-0.084 ***
(Non-granted submis.)$_{t+6}$	-0.091 ***	-0.089 ***	-0.070 ***	-0.190 ***	-0.070 ***
(Non-granted submis.)$_{t+7}$	-0.087 ***	-0.080 ***	-0.076 ***	-0.130 ***	-0.076 ***
(Non-granted submis.)$_{t+8}$	-0.097 ***	-0.101 ***	-0.102 ***	-0.056 **	-0.101 ***
No. obs.	163,337	157,136	132,547	23,821	129,832

Notes: The dependent variable is the yearly wage. Regressions are run on the inventors' sample and use a fixed effect estimation method. Standard errors are always clustered both at the firm and at the employee level. Patent wage premia are computed with respect to the year before submission at EPO. All specifications control for: 19 forward-lags and 19 backward lags of the patent variable, inventors' age, work status, individual fixed effects, sector, region, firm size and time dummies. Variables denoted with * (**) [***] indicate statistical significance at the 10 (5) [1] percent level.