Patent Productivity of German Professors over the Life Cycle

03.09

Sidonia von Ledebur

Philipps Universität Marburg

Impressum:

Working Papers on Innovation and Space
Philipps-Universität Marburg

Herausgeber:

Prof. Dr. Dr. Thomas Brenner
Deutschhausstraße 10
35032 Marburg
E-Mail: thomas.brenner@staff.uni-marburg.de

Erschienen: 2009

Patent Productivity of German Professors over the Life Cycle

Sidonia von Ledebur (later: Sidonia von Proff)[1]

Section Economic Geography and Location Research, Institute of Geography, Philipps-University, Marburg.

Abstract:

The paper studies the patent productivity of scientists over their life cycle. The incentives for patenting and for publishing are compared and how they shape life cycle productivity. In most empirical studies, publication productivity decreases at the end of the scientific career. In contrast, the analytical model given here suggests an increase of patent productivity over the life time. In the empirical part the patents of nearly 1000 German patent active professors are analyzed. The empirical findings support the theoretical prediction that patent productivity does not decline for older scientists.

Keywords: university patenting, patent productivity, scientific productivity, age and productivity, Germany.

JEL Classifications: O33, J24, O34

[1] Corresponding Author: Sidonia von Proff, Philipps-University Marburg, Deutschhausstraße 10, 35032 Marburg, Germany. E-Mail: vonproff@geo.uni-marburg.de.

1 Introduction

The first studies on the question whether productivity differs with age were published as early as five decades ago (Lehman, 1953; Merton, 1957). This question is important for the whole economy due to the aging of the population and for management science the interest lies on efficient compensation schemes. The so-called fluid abilities (in contrast to the experience-related crystal abilities) are known to decline with age as does the ability to adapt to new environments. Neurobiologists disagree whether the age in which the cognitive decline begins is in the late 20s or much later, but they agree that the decline becomes faster for older people (cf. Schaie, 2005; Salthouse, 2009). But productivity also depends on work experience (crystal abilities), which increases with age. In addition, vocational training and job changes may enhance productivity due to new knowledge or increased motivation respectively. These factors shape the productivity profile.

Individual compensation does not necessarily correspond to productivity during lifetime. Lazear (1981) developed a contract theory of labor markets in which younger employees are paid below their marginal productivity while older ones are paid above. Kotlikoff (1988) supported this view empirically and found evidence that the productivity profile follows an inverted U-shape function. However, the productivity of scientists and other creative workers is a special case, because their work is different from that of other employees and especially difficult to monitor. Because some famous scientists were quite young when they made seminal discoveries there is a widely held belief that age is negatively correlated with scientific productivity. But there is little empirical evidence for this opinion, as the discussion of the literature about publishing profiles in the next section will show. Patents are a second kind of output of scientific work (of course depending on the field of research). During the last decades the attention given to technology transfer activities of universities has increased strongly (cf. Von Ledebur, 2009). In this context, academic have attracted notice and by now, patent activities are regarded as a third task of academic scientists besides teaching and research. The paper at hand will explain why patenting and publishing are different tasks for scientists and how patent profiles time could differ from publication profiles over the life time due to these differences. There are hardly any studies on patent productivity of academic scientists (cf. Dietz and Bozeman, 2005 and Azoulay et al., 2006, which are presented below) and to the author's knowledge there is no German one. This is at least partly because the number of academic patents is quite limited in comparison to publications. Since most scientists in patent relevant fields of research hold none or only one patent it is not possible to analyze lifetime patenting profiles on an individual level. Secondly, inventors appearing on patents and professors employed at universities are rather difficult to determine as the same person. However, an analysis on an aggregated level is possible, leading to a grasp of general patterns of patenting activities. The paper at hand is a first approach to fill this research gap. A database which contains data on about 1000 German professors and their patent applications created for a previous paper appears as a useful starting point to investigate the issue of patent productivity in Germany (cf. Von Ledebur et al., 2009).

The remainder is structured as follows. The next section discusses literature on the productivity of scientists. Section three comprises the discussion why patenting and publishing are different tasks for scientists as well as an analytical model about lifetime productivity of scientists and hypotheses resulting from it. The challenges of analyzing the relationship between age and productivity will be discussed in section four and here the database is presented as well. Afterwards the empirical findings for German professors will be presented and discussed in section five before section six concludes the paper.

2 Literature review

Research on labor productivity of scientists with regard to their age goes back to the 1950s. At first, Lehman (1953) gave some examples that seminal scientific discoveries were made in younger days. Merton argued that research is done for future reward and recognition. Due to the "Matthew Effect" in science, i.e. the self-reinforcement of reputation, early reputation is very important to get reward later (Merton, 1957/1968). Therefore young scientists work hard to publish sufficiently in the hope of later recognition while receiving a rather small remuneration at the beginning.

This implies that marginal productivity changes with age not only due to reduced cognitive abilities but also due to changed incentives. At the beginning of the career, scientists have to show their ability and to gain reputation in order to get tenure positions and earn more money later. The expected years of future reward become less when they become older. The discounted value of the remaining lifetime reward is more and more outbalanced by the costs of doing research. In a formal model, Diamond (1984) shows that quality and/or quantity of publications decrease with age.

The largest empirical study among the early research in this field was done by Bayer and Dutton (1977). They find for most of the 7 fields under observation a two-peak profile with lower productivity at the beginning and the end of the life time. Levin and Stephan (1989) confirm a decline (not continuously, but overall) in publication productivity for four fields of research (biochemistry, earth sciences, physics, and plant and animal physiology). This finding holds for different measures of publication productivity (total and weighted counts of publications). In a subsequent formal and empirical model they add the differing "taste for research" as another reason why scientists are more or less productive (Levin and Stephan, 1991). Their longitudinal data of US scientists show an inverted U-shape function of publication productivity for several subfields of the fields mentioned above. The peaks depend on the type of productivity measure and on the field. The most productive ages vary between 39 (atomic and molecular physics) and 59 years (geophysics). When solving the puzzle gives an especially high satisfaction, the decline can become less pronounced. The two authors find evidence that research activity over the life cycle is investment motivated. An inverted U-shape function is also supported by Cole (1979). This holds for quantity (number of publications) as well as for quality (citations). He adds another reason for declining productivity: while all scientists take great pains at the beginning of the career, those scientists who do not get sufficient recognition for their research are discouraged and publish less in the later stages of their career. However, all these regressions explain only a comparably small part of the variance in productivity. Other individual factors seem to have greater influence.

More recent research of Hall et al. (2007) on French physicists suggests a secondary peak in the publication productivity at an age around 50 years. Similarly, Dietz and Bozeman (2005) find a higher productivity of older PhD cohorts for both publications and patents. The caveat is that younger cohorts in their dataset may not have reached their peak of productivity yet. This study is one of the few which analyze the patent productivity of scientists. The focus of Dietz's and Bozeman's work is not on age effects but on the effects of job mobility, therefore the results do not directly show the relation between age and productivity. Azoulay et al. (2006) find a patent productivity peak in the middle of the career in a study of life scientists (in a broad sense) in the US. This finding is a by-product of their investigation of the relationship between publishing and patenting. In summary, most studies on publication productivity find a decline, either from the beginning on or after a peak during the career. In contrast, the question how patent profiles over the life cycle of scientists look like still remains unanswered. In the next section, the difference between patenting and publishing activities is discussed.

3 Scientific productivity and age

3.1 Theory

The reward structure in science is quite special and not comparable to that of other types of work. Among the problems regarding the production of new knowledge is that *ex ante* it is unknown what will be produced and *ex post* the value of the new piece of knowledge is unknown. The rewards often accumulate over a quite long period and the researcher cannot obtain the whole reward. Therefore, a patronage system is common for the science system: the government takes financial responsibility for the development of new knowledge by financing public research institutions, universities and other research institutes are cases in point.[1] Governmental funding in the open science system requires a reward system based on reputation to ensure quality. Therefore scientists are interested in quickly

[1] See David (1994) for a description of the different reward systems for knowledge production.

publishing their findings in order to be known as the first one who found or developed something. A referee system serves as a control institution. This system has been established over decades and it is very successful, so that publications are often the only source for academic reputation, which has a negative effect on the interest of scientists to engage in other forms of knowledge and technology transfer (see for example Antonelli, 2008 ; Stephan, 1996; Dasgupta and David, 1994).

When scientists engage in patenting, there must be special incentives to do so. A direct financial incentive is the hope to earn money by licensing or selling a patent. In negotiations with industry scientists have a better bargaining position when offering intellectual property rights over the results in exchange for research funding. In addition, patents on prior inventions signal closeness to industrial applications. This attracts industry funding as well as students interested in application oriented research. All these incentives to patent are weaker than those to publish as long as publications are the main parameter responsible for tenure and promotion. In Germany, it is not common to have associate professors or tenure tracks. After completing the PhD scientists have temporary work contracts with medium payment for several years until they are able to achieve a professorship. When they succeeded to become a professor, they are civil servants and have a permanent position. In the past, being a professor was connected to a relatively fixed salary and a high publishing level was only necessary for gaining a position at another university (and reputation). Lately, the compensation system has begun to change towards payments that are at least partly performance-related.

The empirical studies on publication productivity presented in section two all analyze the US system, but regarding the considerations above about the German science system a publication profile like an inverted U-shape can be assumed for Germany as well. The regulation for professors in other countries differs from that in Europe, e.g. the status as civil servants does not exist everywhere while other countries may have tenure tracks even for younger scientists. Nevertheless, it is inherent to academia that the career path depends heavily on publications and once being a professor your position is quite secure.

While the publication incentives (except intrinsic motivation) are reduced, the patent productivity does not necessarily decrease with age. The German system implies that, once being a professor, an individual can be interested in more industry contacts in order to earn additional money by consultancy and mission-oriented research. Thus, the engagement in patent activities can be expected to take place later in the career whereas at earlier stages the focus is on publications. After becoming professor, financial rewards exceeding the employment contract become more attractive, so patent productivity can be assumed to increase over the whole work life time.

A second factor in favour of an increase in patent productivity with age is that patenting requires special skills and knowledge. Even though an invention is possible as an idea of a genius, inventions normally derive from a profound knowledge of a field of research which often crosses disciplinary boundaries. Different knowledge pieces have to be combined in order to derive an invention that is patentable (according to European patent law an invention has to be new, non-obvious, and an inventive step has to exist). Thus, most inventions are derived in teams (cf. Schmookler, 1957). In the dataset described later in section 4 it can be observed that patents are usually filed by a group of inventors: nearly 25% of the patent applications name 5 or more inventors, while only 11% of the patent applications come from single inventors. Additionally, some market knowledge is necessary because a patent can only be filed with a certain idea of application in Europe. That means patentable inventions require broader knowledge than publications which can be restricted to a very specialized problem. To build up this combination of an overview over the field and detailed, specialized knowledge as well as some information of potential markets takes many years. With time the probability of industry contacts and technology transfer office connections increases. After gaining experience in the patenting process it becomes easier to file another patent. Therefore, professors engaging in patenting usually do so again (cf. Brenner and von Ledebur, 2009), while the majority of professors never file a patent.

3.2 Model

In the following, the productivity over the life cycle will be investigated analytically. Professors split their working time *T* between three tasks: teaching *t*, doing research *r* (publishing), and engaging in technology transfer *p* (patenting).

$$T = t_t + t_r + t_p \qquad (1)$$

For each hour of teaching they get a fixed wage *w* and there is a lower limit of necessary teaching hours. In period *i* the income *V* from teaching is:

$$V_{ti} = w t_i \;;\quad t_{ti} \geq t_{t,min} \qquad (2)$$

The payment for doing research depends on the cumulative time spent for it. This payment is related to the advancement in the scientific career, and contains paid presentations and awards as well. When people are already famous, have a well-paid position and maybe even receive honorarium for giving a presentation, an additional published paper will hardly increase the income. Therefore, the return is decreasing on the margin. There is a constant c_r added for securing a positive starting income and a linear depreciation of the knowledge α. This is necessary, because most research loses value over time. Newer findings can make older ones obsolete. In period *i* the income from doing research is:

$$V_{ri} = \beta_r \Big(\sum_{j=1}^{i} t_{rj} + c_r - \alpha i\Big)^{\gamma_r} \;;\ \gamma_r < 1 \qquad (3)$$

The payment for patenting depends on the cumulative effort as well, but with increasing or constant marginal return. The reason is that one needs experience in patenting in order to be successful and the return is not a lump-sum payment at the end of the period but rather flows during several years. In period *i* the income from patenting is:

$$V_{pi}=\beta_p(\sum_{j=1}^{i} t_{pj}+c_p)^{\gamma_p}*(\sum_{j=1}^{i-1} t_{rj}+c_r-\alpha i) \;;\;\; \gamma_p\geq 1 \qquad (4)$$

The last factor ensures that it is not possible to stop doing research completely. The knowledge loses value over time (depreciation term *αi*) and without spending time for research it will become impossible to continue patenting after some time. That means the last factor contains the interdependency of doing research and patenting.

The income of the time spent for publishing and patenting must exceed that of having taught the same amount of time, otherwise the professor would constrain himself to teaching. If that is the case, the time spent for teaching is always as low as possible ($t_{ti}=t_{t,min}$ or $t_{ti}=T$). The first case is the interesting one, because there is time left to be spent for research and patenting. Thus, let us now analyze the case where $t_{ti}\geq t_{t,min}$.

The scientist wants to increase his income, but he is myopic, i.e. spends the money for the task, where the increase in income is maximal during the next period. He is limited rational in the way that he calculates the change in income: he takes the marginal income from the deviation of last period's income and does not take into account how the time spent for one task influences the marginal income from the time spent for the other task. That means the reciprocal effect of the time allocation and the change of the marginal income is excluded; instead, the marginal income is taken from the deviation of last period's income. Due to the myopia we do not face a common maximization problem that can be solved exactly.

But, since $\gamma_r-1<0$ and $\gamma_r-1<0$; the partial derivative $\frac{\partial V_r}{\partial t_r}$ decreases with time, while the partial derivative $\frac{\partial V_p}{\partial t_p}$ increases with time (in the linear case it stays constant). Thus, the time allocation shifts from doing research with the aim of publication towards more time spent for patenting activities. The exponents determine the speed of the shift.

The result of this simple model is that professors can be expected spend more time for patent activities when becoming older. In order to set the time spent for patent activities in relation to the amount of patent applications an assumption about the productivity is necessary. A cognitive decline would result in lower numbers of patents per time unit. The empirical studies presented in section two stated different ages for productivity peaks, some of them being quite near to retirement. Therefore, it can be assumed that the increase in time effort outbalances the longer time needed for one patent so that overall the number of patents per year is non-decreasing for scientists becoming older.

3.3 The Hypotheses

The preceding considerations lead to several hypotheses. According to the last two sections the incentives for patenting activities increase over the life time.

Hypothesis 1: The number of patent applications per professor increases on average with age.

The need to combine the knowledge pieces of several persons in order to derive patentable inventions was highlighted above. Most inventions are the result of team work (Schmookler, 1957). The network of a scientist can be expected to be larger later in the career after having met other scientists on hundreds of conferences. At the same time, the number of research fields covered by the acquaintances can broaden. Thus, it is easier to find help with interdisciplinary problems – and more often other scientists will ask for support. Experience shows that interdisciplinarity is a rather new phenomenon and many researchers in the past did not look beyond their own nose. A possible age effect is more likely based on a larger network in the own field of research than based on interdisciplinary contacts. As Lissoni and Montobbio (2008) explain, inventorship on a patent is more restricted than authorship on a publication. Therefore, senior professors should not appear on their assistants' inventions as it may happen on publications. If there is an age effect in the number of inventors, it should be just the effect of the larger network that comes along with age.

Hypothesis 2: The number of inventors involved in a patented invention is larger for older scientist.

The arguments above are not independent from each other. The larger network of scientists increases the possibility to be involved in new patent projects, i.e. the probability of filing a patent increases in this way indirectly. And having filed a patent can increase the scientific network, because other professors interested in patenting activities become aware of colleagues with similar interests. In sum, broad knowledge stocks as well as connections to other researchers are gained during the career. The process starts early in the career and the learning curve slows down with age. Later, the exploitation of the knowledge stock and the network comes to the fore and the size of the inventive step can be assumed to decrease over time. More radical inventions need more new or interdisciplinary knowledge than ageing scientists accumulate. Interdisciplinary connections Therefore, the quality of patents could decrease with age.

Hypothesis 3: Higher scientific age is related to lower-quality patents.

Regarding Hypotheses 1 and 3 jointly, it is not straightforward which effect is stronger. Thus, we cannot say whether the amount of patented knowledge increases with age. This problem will be addressed later again.

The literature review section showed differences in the publication profiles for different fields of research. This holds similarly for patents. Some fields are closer to industrial application than others. The low absolute numbers of patents in most fields make it impossible to analyse all of them separately. But broadly spoken, engineering departments can be expected to be closer to industrial application than natural and life sciences which do a lot of basic research.

4 Method and Data

The empirical research on the relationship between age and productivity brings certain challenges with it. When identifying age effects two further effects at work have to be taken into account: the cohorts of the individuals and the periods under investigation. Cohorts (defined for example by the start of the scientific career) differ from each other, if the characteristics of each group change over time, by sociological change or common life experiences. Period effects appear when data is collected over a time span in which e.g. technological change takes place. If the cohort is not defined by the biological age, then the cohort plus the period equals the age. Thus, in a linear model only two of the variables can be distinguished. There are several approaches to handle this problem like a cohort study or using cross-sectional data (Hall et al., 2007 discuss the handling of the three effects in detail).

In the paper at hand pooled data will be used (cf. equation 6 below). The level of patent activities is not high enough to analyze individuals, single cohorts, or periods of one year only. Thus, the analysis has to be restricted to the age/experience variable, because individual or institutional determinants cannot be included. However, when the number of individuals and institutions in the database is large enough, such effects should be leveled out. The database (as described in detail in von Ledebur et al., 2009) contains more than 5,500 patent applications of nearly 1000 German professors. Only patent active professors at public universities are included in the analysis (in all fields of research where patenting is possible, i.e. natural sciences, engineering, life sciences). Since the number of professors in Germany in fields relevant to patenting was quite stable during the period of observation, this is no limitation of the analysis. The period under investigation is 1991 to 2006. Due to the publication delay of 18 months for patent documents newer data could not be included. Additional information in the sample contains for each patent whether it is a German or European application, the family size (number of patent documents with different country code) as well as the inventor's field of research, year of PhD, and gender. The scientific age equals the years since completing the PhD. The range of years in which the PhD was completed is from 1955 to 2003. In order to ensure a sufficient amount of data the scientific age (vintage) at the time of the patent application was pooled as follows.

$$Productivity_v = \sum_t Patents_{vt} / \sum_t Professors_{vt} \qquad (6)$$

In the formula, v is the vintage at the time of the patent application and t the period. In other words, I sum up all patents filed at a certain scientific age in any of the periods and divide the result by the number of professors which have the respective vintage at any one of the time periods under investigation. The resulting productivity profile will be observed graphically and it will be tested whether there is a significant trend. Note that patent productivity is used here as the average number of patents per professor and year and not the number of patents per working hours of a single person. Thus, higher patent productivity may be due to more efficient patent activities or due to a higher time effort.

In order to check whether the results are biased by period or cohort effects the same procedure will be done for two cohorts and one period.

The quality of the patents is measured in two ways. First, the number of patent documents with different country codes is counted. This is often called the size of the patent family. It displays the geographical coverage of the patent protection the applicant seeks. Since the protection in each country has to be paid, only inventions with high enough market potential will have large patent families. Second, a dummy variable indicating whether the patent application was filed directly at the EPO (European Patent Office, then *epo* = 1) is used. This type of application is more expensive than a national one and therefore it is used only inventions with sufficient market potential (as assumed by the applicant).

5 Results and discussion

5.1 The relationship between age and productivity

The data show a non-decreasing patent productivity over the life time for German professors (see Figure 1). Even prior to finishing the PhD some scientists engage in patenting and others still do so after retirement. If the average age at PhD is assumed to be around 30 and the age of retirement 65, it is expectable that the number of professors with patents declines sharply above a scientific age of 35 which leads to a rather volatile number of patents per professor. Therefore I cut off the data at this vintage.

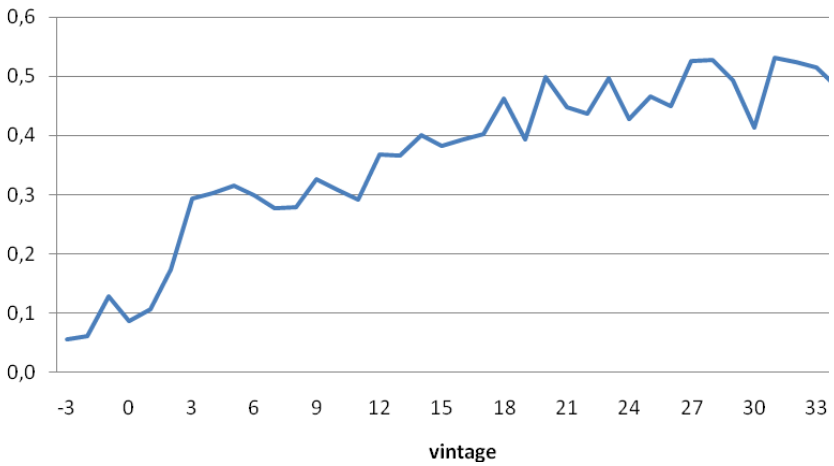

Figure 1: Patent productivity over the life cycle

The graphical observation suggests a linearly increasing productivity until about 20 years after the PhD and then stagnation for the rest of the career. A simple linear regression indicates a yearly increase of 0.011 patents per professor and the regression is highly significant (assuming a square-root shape of the profile is also highly significant, cf. Appendix A). Due to the use of pooled instead of individual data, these values are not comparable to the low explanatory power of the publication profile models presented in section two. Regarding the highly skewed distribution of patents among inventors, it is obvious that age explains only a small part of patent productivity as well.

Limiting the analysis to two cohorts (PhD year 1971-74 and 1981-83, selected in the way that they contain at least 800 patents) shows a similar profile (see Figure 2) with stagnation from the first peak at $\upsilon=23$ on for the older group and $\upsilon=17$ on for the younger group. In both cases the last observation raises a question (possible upward/downward trend). More recent data will be necessary to investigate the further development of patent applications.

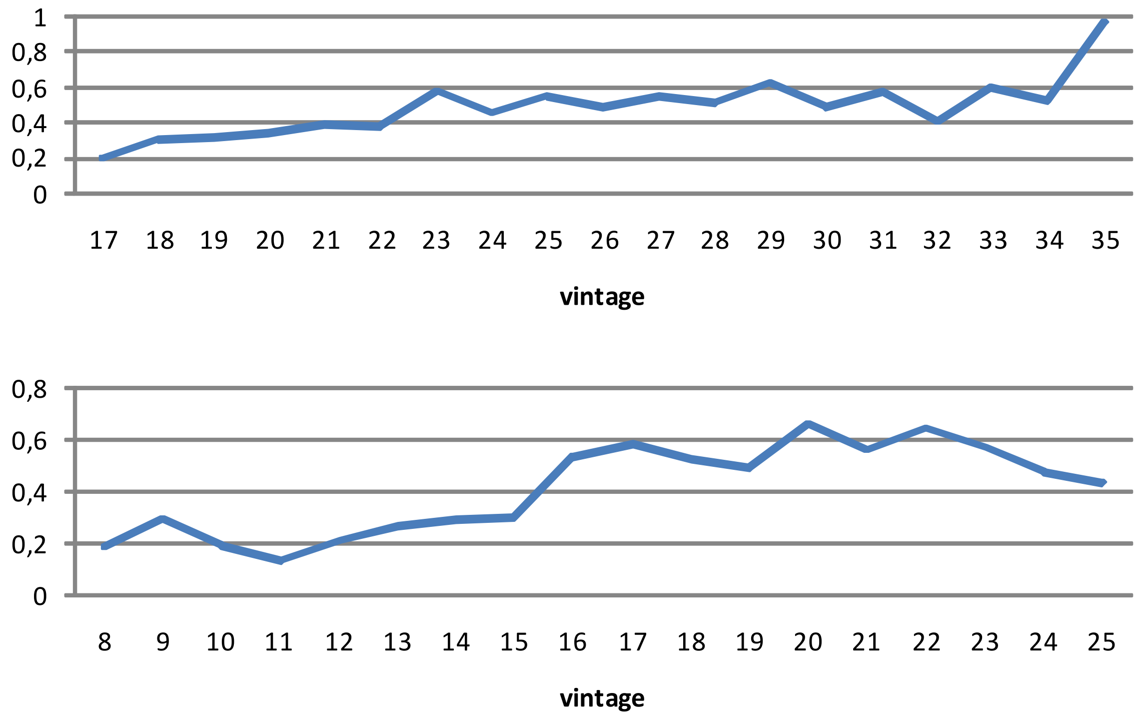

Figure 2: Patent productivity 1991-2006 of two cohorts (above: PhD years 1971-1974; below: 1981-1983).

Interestingly, the older cohort starts in 1991 at the same level as the younger one: in both cases the scientists file about 0.2 patents per year. This suggests period effects, i.e. the increase could be due to an overall increase in patenting instead of vintage effects. The overall trend in the underlying database (number of patent applications per year) is an increase in patenting, which is especially strong during the mid-1990s. The number of first-time patenting professors increased in parallel (von Ledebur, 2009). Nevertheless, it is possible that the number of patents per professor could have increased due to the overall increased awareness for patent issues. The scientific age differs so much in the database that the number of patents for each age is very small when regarding only one period. Therefore, I study the period 2003-2006 (there is no clear trend in the absolute number of patents in these years) in order to obtain a sample of nearly 2,000 patents for an analysis without period effects. The rather volatile data suggest an upward trend in patent productivity for the first ten years of the scientific career and then stagnation, while the initial increase lasts longer in the other analyses.

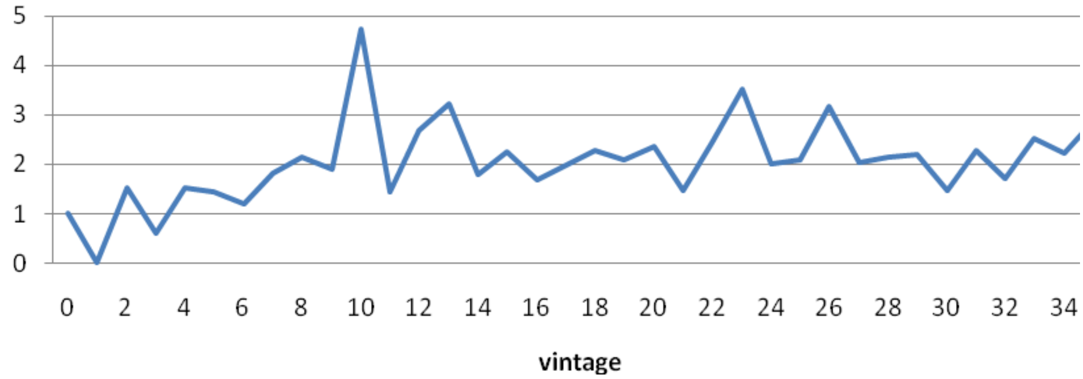

Figure 3: Patent productivity 2003-2006.[2]

In summary, in all samples analyzed here there is evidence for an increase in scientists' patent productivity for at least the first ten years after completing the PhD. Since the trend in the age and patent profile for the shorter period does not differ substantially from the overall or cohort trend, no evidence for strong period effects was found. Only, the number of professors engaged in patenting activities increases during the period of observation. Linear and logarithmic regressions support the graphical impression of increasing productivity. In none of the samples we find a decrease in patent productivity. Thus, Hypothesis one is supported in so far as there is no decrease in patent productivity, though, after a certain age there is no further increase. The upper limit of productivity is reached somewhere between 10 and 20 years after the PhD. In Germany, this usually means at an age between 40 and 50, which corresponds to the findings regarding publication peaks.

As can be seen in Table 1, there is a positive significant correlation between the number of inventors appearing on a patent application and the vintage of the professor. This supports hypothesis 2, stating that the scientific network becomes larger with age. The correlations between vintage, the size of the patent family (*famsize*), and a dummy variable which equals 1 if a patent was filed directly at the European Patent Office (*epo*) are also displayed in Table 1.

2 Note that the overall level seems to be higher in Figure 3 only because a period of four years is used.

Table 1: Correlation between vintage, two quality measures, and the number of inventors.

	vintage	epo	famsize	# of inventors
vintage	1	-,042(**)	-,092(**)	,098(**)
p-value		,002	,000	,000
n	5541	5541	5541	5541
epo	-,042(**)	1	,127(**)	,058(**)
p-value	,002		,000	,000
n	5541	6127	6127	6127
famsize	-,092(**)	,127(**)	1	,097(**)
p-value	,000	,000		,000
N	5541	6127	6127	6127
# of inventors	,098(**)	,058(**)	,097(**)	1
p-value	,000	,000	,000	
n	5541	6127	6127	6127

** significant (Pearson) at 1%.

Indeed, the employed quality measures indicate a decline in quality with increasing age of the scientists. This supports Hypothesis 3. Together with the previous finding that the number of patents per professor stagnates after an increase over several years this declining quality means an overall decrease in the amount of patented knowledge.

These findings are in line with the model of Diamond (1984) on publication productivity cited above, who argues that quality may decline even if quantity stays constant. Regarding quantity and quality of patent applications jointly, our findings correspond to an inverted U-shape function, which suggests that patenting and publishing may not be as different as assumed before.

5.2 Field Differences

The literature on publication productivity shows differences between the fields of research. Due to limited data, the patent productivity can be separated only for the most prominent fields. In Germany these are chemistry, mechanical engineering, and the life sciences. The assignment to the subject follows the department of the professor.

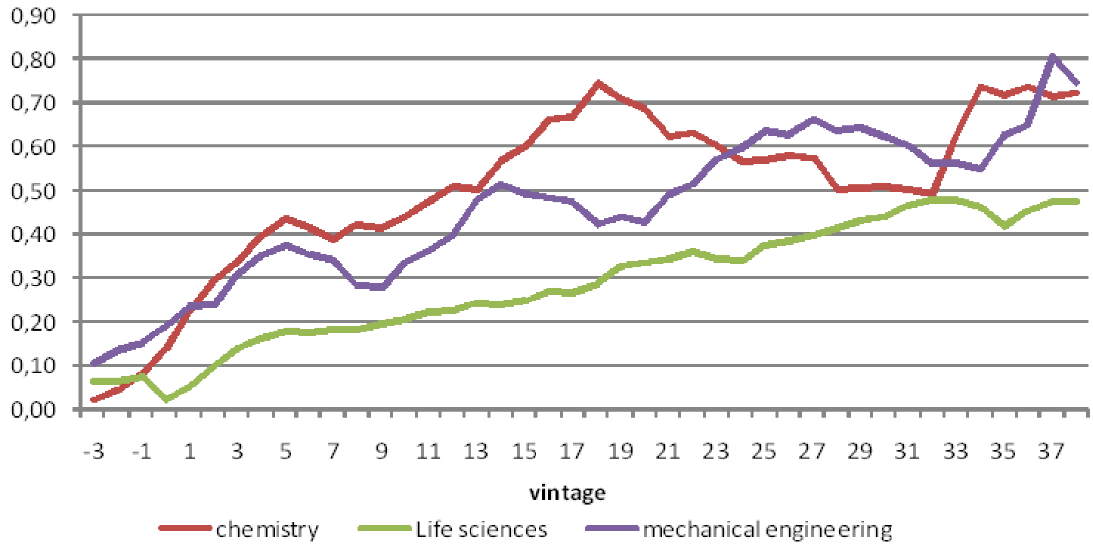

Figure 4: Patent productivity in certain fields, 5 year moving averages.

As can be seen in Figure 4, there are indeed differences between the subjects: in the life sciences the increase is remarkably linear over the whole life cycle, chemistry shows a clear peak with a following decrease, and in mechanical engineering an overall increase with intermediary periods of decline can be found. The patent productivity over the whole life cycle is lower in the life sciences than in the other two fields (t-test is significant), which suggests that chemistry and mechanical engineering are closer to industrial application (t-test does not show a difference between chemistry and mechanical engineering, see Appendix B). Since mechanical engineering is a subject not investigated in the studies of publication productivity, no comparison is possible. Regarding the other subjects, Levin and Stephan (1989) study biochemistry and physiology among others. The former one is in this study a part of the subject chemistry; and similarly to our patent data, biochemistry has the highest overall publication productivity and a rather early peak in productivity. However, the physiology profile looks very different to the patent profile of the life sciences and seems to be non-comparable due to the broad definition of life sciences used here. The often observed physicists have a patent activity too low to be analyzed separately.

6 Conclusion

While several authors have investigated publication productivity of scientists, patenting has been largely neglected. The paper at hand analyzes patented inventions of German professors. Due to the rather low number of university-invented patents pooled data is used to generate age and patent profiles. By doing this, individual factors influencing patent decision cannot be included. Thus, the paper at hand can focus only on a single relationship: the one between scientific age and patent productivity. The main result is that the number of patent per professor increases for the first 10 to 20 years of the scientific career and then stagnates. This finding is robust, as a check for cohort and period effect shows. Furthermore, the number of inventors involved in a patent application increases with age and at the same time quality decreases. Two quality measures have been used, the direct application at the EPO and the size of the patent family. Taking into account the results on quantity and quality jointly suggests a decrease of the overall amount of patented knowledge. The productivity profile corresponds to the one of publications. The results suggest that patenting and publishing may not be as different as assumed before.

Regarding the increased emphasis of academic patenting, the effects of policy measures may need more time to become visible. An increase of the patent awareness of younger scientists may result in a higher patent productivity not until many years later.

7 References

Antonelli, Cristiano, 2008, “The new economics of the university: a knowledge governance approach”, *The Journal of Technology Transfer*, 33(1), 1-22.

Azoulay, Pierre; Ding, Waverly, and Stuart, Toby, 2006. “The Determinants of Faculty Bahavior: Demographics or Opportunities?” NBER Working Paper 11348.

Bayer, Alan E. and Dutton, Jeffrey C., 1977. “Career age and research-professional activities of academic scientists”, *Journal of Higher Education*, 48(3), 259-282.

Brenner, Thomas and von Ledebur, Sidonia, 2009, “Academic inventors’ decision on a transfer channel – the influence of commercialisation experience”, Marburg Working Papers in Innovation and Space Vol. 01.08.

Cole, S., 1979, “Age and Scientific Performance”, *American Journal of Sociology*, 84(4), 958-977.

Dasgupta, Partha and David, Paul A., 1994. “Toward a new economics of science”, *Research Policy*, 23(2), 487-521.

David, Paul, 1994, “Positive Feedbacks and Research Productivity in Science: Reopening Another Black Box”, in: The Economics of Technology, Ove Granstrand (ed.), Amsterdam: Elsevier Science, 65-89.

Diamond, A., 1984, “An economic model of the life-cycle research productivity of scientists”, *Scientometrics*, 6(3), 189-96.

Dietz, James S. and Bozeman, Barry, 2005, “Academic careers, patents, and productivity: industry experience as scientific and technical human capital”, *Research Policy*, 34(3), 349-367.

Hall, Bronwyn, Mairesse, Jacques and Turner, Laure, 2007, “Identifying Age, Cohort, and Period Effects in Scientific Research Prodcutivity. Discussion and Illustration Using Simulated and Actual Data on French Physicists”, *Economics of Innovation and New Technology*, 16, 159-177.

Kotlikoff, Laurence J., 1988, “Estimating the Age-Productivity Profile Using Lifetime Earnings”, NBER Working Paper 2788.

Lazear, Edward P., 1981, “Agency, Earnings Profiles, Productivity, and Hours Restrictions”, *American Economic Review*, 71(4), 606-620.

Lehman, Harvey C., 1953. Age and Achievement. Princeton: Princeton University Press.

Levin, Sharon G. and Stephan, Paula E., 1989, “Age and research productivity of academic scientists”, *Research in Higher Education*, 30(5), 531-549.

Levin, Sharon G. and Stephan, Paula E., 1991, “Research productivity over the life cycle: evidence for academic scientists,” *American Economic Review*, 81(1),114-32.

Lissoni, Francesco, and Montobbio, Fabio, 2008. “Guest authors or ghost inventors? Inventorship attribution in academic patents”, Paper presented at the DRUID 25th Celebration Conference, Copenhagen.

Merton, Robert K., 1957, “Priorities in Scientific Discovery: A Chapter in the Sociology of Science”, *American Sociological Review*, 22(6), 635-659.

Merton, Robert K., 1968, “The Matthew Effect in Science: The reward and communication systems of science are considered”, *Science*, 159(3810), 56-63.

Salthouse, Timothy A., 2009, “When does age-related cognitive decline begin?” *Neurobiology of Aging,* 30(4): 507-514.

Schaie, K. Warner, 2005, “Developmental Influences on Adult Intelligence: The Seattle Longitudinal Study”. New York: Oxford University Press.

Schmookler, Jacob, 1957, “Inventors Past and Present”, *The Review of Economics and Statistics*, 39(3), 321-333.

Stephan, Paula E., 1996, “The Economics of Science”, Journal of Economic Literature, 24(3), 1199-1235.

Von Ledebur, Sidonia, 2009, “University-owned patents in West and East Germany and the abolition of the professor's privilege”. Marburg Working Papers on Innovation and Space Vol. 02.09.

Von Ledebur, Sidonia; Buenstorf, Guido and Hummel, Martin, 2009, “University patenting and the abolition of the professors’ privilege in Germany 1991-2006”, Jena Economic Research Papers No. 2009-068..