

# Leisure Time Invention – Waste of Effort, or Wellspring of Breakthrough Ideas?

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## ABSTRACT

This paper seeks to add to our understanding of how the creative process might affect patent value by investigating the possible effect of a further, as yet unexplored characteristic, “leisure time invention,” where the main insight leading to the invention emerges when the inventor is not engaged in paid work. Leisure time inventions, if mentioned in the literature at all, are disparaged as being of marginal importance and low economic value. But anecdotal evidence (for example, the invention of 3M’s highly successful Post-It Notes) suggests that this may not necessarily be the case. One might speculate that a problem-solving process where an inventor chooses to be engaged *without* being paid – and is thereby “freed” from the normal work time pressures – could lead to unconventional, less path-dependent search processes, increasing the probability of making more valuable inventions. Based on data from an inventor survey, we show that patents granted to leisure time inventions are more valuable than patents granted to work time inventions. Moreover, the size of the ‘leisure time effect’ on patent value increases with the value of the patent.

## 1 Introduction

Empirical studies of the determinants of patent value focus primarily on the characteristics of the patent itself, or of the applicant. These determinants include the remaining term of protection (Pakes, 1986; Schankerman and Pakes, 1986; Lanjouw *et al.*, 1998), the scope of protection (Lerner, 1994; Harhoff *et al.*, 1999; Harhoff and Reitzig, 2004), the type and number of applicants or patent owners (Harhoff and Reitzig, 2004; Guelle and van Pottelsberghe, 2000), the number of claims (Tong and Frame, 1992; Lanjouw and Schankerman, 2001), and the technical field (Harhoff *et al.*, 1999; Guellec and van Pottelsberghe, 2000). Only a few empirical studies analyze aspects of the relationship between the characteristics of the creative problem-solving process leading to an invention and patent value. Gambardella *et al.* (2008) and Hoisl (2007) provide empirical evidence that the use of different sources of knowledge during the process leading to an invention positively affects patent value. Harhoff and Hoisl

(2007) demonstrate a positive relationship between motivation and incentives and patent value. This paper seeks to add to our understanding of how the creative process might affect patent value by investigating the possible effect of a further, as yet unexplored characteristic, “leisure time invention,” where the main insight leading to the invention emerges when the inventor is not engaged in paid work.<sup>1</sup>

In the literature on inventive problem-solving, scholars have primarily analyzed how to enhance organizational creativity – and thereby performance (see, for example, Zhou and Shalley, 2008). Studies indicate that a supportive and stimulating work environment as well as autonomy foster creative performance (e.g., Oldham, 2003; Hackman and Oldham, 1980), whereas high workload and time pressures have a negative effect (e.g. Amabile et al. 1996; Shalley et al. 2004). Other researchers have examined the creative process in the context of lone and independent inventors. A key finding is that inventions made by independent or lone inventors are characterized by a higher variability in value. Even if the average value of these inventions might be lower than that of collaborative inventions, the probability that they represent breakthrough invention is much higher (Fleming 2006; Åstebro 2003; Nelson 1959).

Leisure time inventions, if mentioned in the literature at all, are disparaged as being of marginal importance and low economic value (e.g., Dahlin *et al.*, 2004; Rosenberg, 1994). But anecdotal evidence suggests that this may not necessarily be the case. An example of a highly successful leisure time invention is 3M chemist William Fry’s irritation over bookmarks that fluttered out of his hymnal while at choir rehearsal. This eventually contributed to the development of 3M’s breakthrough invention of a weak adhesive, which formed basis for the company’s enormously profitable ‘Post It Notes.’<sup>2</sup>

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<sup>1</sup> In the questionnaire (see Section 2, below), inventors were asked to choose among three possible sources of inspiration for their patented invention:

*“Which of the following scenarios describes best the creative process that led to your invention: (1) The invention was made in the course of a research and development (R&D) project (2) I got the idea underlying this invention during my normal job (which is not R&D) and (3) I got the idea underlying this invention during my leisure time”.*

<sup>2</sup> Many examples of valuable leisure time inventions could be mentioned. Perhaps the most well-known concerns the invention of the Wright brothers’ “flying machine. The brothers’ crucial insight came from observing how vultures bank their wings when turning in flight. Until then, the problem of how airplanes could turn safely had bedeviled fliers, not infrequently with fatal results (Heinsohn, 2007). To take another example, Wozniak and Jobs build the first prototype for the Apple computer in Jobs’ parents’ garage (Åstebro, 2003).

To define leisure time invention, we turn to the studies on “time commitments,” which explore how people divide their time between different types of activities (e.g. Bittman and Wajcman, 2000, Goodin et al., 2005, Robinson and Godbey, 1990). Four categories of time are distinguished: paid work time (at the workplace, or at a home work-station), unpaid household time (cooking, cleaning, shopping, caring for children and so forth), personal care time (eating, sleeping, grooming and so forth), and a residual category, free time, which is the time left over after the activities in the other three categories (such as socializing, culture, hobbies, other recreation, and watching TV). On this basis, we define leisure time inventions as inventions where the main inspiration occurred while the inventor was engaged in one of the three unpaid categories specified above. Such inventions may be further developed during the employee’s leisure time, or at the workplace, or both.<sup>3</sup>

The relationship between the leisure time inventive insight and the value of the patent on the resulting invention has never been tested. However, one might speculate that a problem-solving process where an inventor chooses to be engaged *without* being paid – and is thereby “freed” from the normal work time pressures – could lead to unconventional, less path-dependent search processes (Fleming and Sorenson, 2004). “Combinative capability,” the ability to move beyond local search to generate new combinations of existing knowledge, increases the probability of making more valuable inventions (e.g. Kogut and Zander, 1992; Rosenkopf and Nerkar, 2001).

Based on data from an inventor survey, we show that patents granted to leisure time inventions are more valuable than patents granted to work time inventions. Moreover, the size of the ‘leisure time effect’ on patent value increases with the value of the patent.

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<sup>3</sup> This definition means that activities like changing diapers, eating or watching TV, even if they are neither voluntary nor intrinsically motivating, may still be the source of a leisure time insight. An example concerns the invention of Pampers, commercially introduced by Procter & Gamble (P&G) in 1961. The first disposal diaper had been invented by Chicopee Mills (Chux) in 1932. But by 1956, Chux and the other early disposable diapers only accounted for 1% of diaper changes in the United States, due to their high relative cost, high leakage (they were made of tissue paper), and the fact that they had to be anchored by safety pins. In that year, P&G acquired a paper pulp plant. Management asked Victor Mills, a P&G chemical engineer, to figure out what to do with it. Mills, also a grandfather, remembered how he hated changing diapers – and then he had his sudden insight: might using cellulose fibers instead of tissue paper increase diaper absorbency? His team got to work, and ten years later, P&G finally introduced a high quality, low cost diaper – which became an instant success! (Markides and Geroski, 2004: 92-94).

## 2 Data and Variables

Our data derive from the PATVAL-EU6 inventor survey (Giuri and Mariani *et al.*, 2007). A total of 10,500 inventors who lived in Germany at the time of their invention were selected from a list of all granted EP patents with priority date between 1993 and 1997. As addressee of the questionnaire, the first inventor listed on the patent document was contacted. 3,346 responses were received (from 3,049 different inventors), resulting in a response rate of 33%.<sup>4</sup>

To measure patent value, we use two different variables: asset value, and size of the patent family. As regards the first, the surveyed inventors were asked to estimate the price they believed their firm would ask a competitor to pay if the competitor wanted to buy the patent<sup>5</sup>. Thus this variable reflects the *inventor's* own assessment of the value of patent on her invention (Harhoff *et al.*, 2003). Our second measure, the size of the patent family, refers to “the number of jurisdictions in which patent protection was sought for the same invention” (Harhoff *et al.*, 2003, p. 1345). For each additional country, the applicant has to pay for a translation into the national language, for the validation of the patent, and

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<sup>4</sup> A non-response analysis was conducted based on the full dataset, consisting of 10,500 granted EP patents. A probit model was used, estimating the probability of an answer as a function of a number of explanatory variables. In particular, procedural information on the respective patents obtained from the online EPOLINE database of the European Patent Office was employed, such as the priority date, the number of claims, the incident of an opposition, the size of the patent family, the grant lag (time lag between application and grant date), and the size of the inventor team (total number of inventors listed on the patent document). Due to the large sample ( $N = 10,500$ ), only results significant at least at the 1% level were considered as possible sources of a non-response bias. Two variables exhibited a significant effect, the size of the patent family and the size of the inventor team. In particular, each additional country decreased the probability of an answer by 0.4%. In the dataset, the number of designated states varies between 1 and 18. Therefore, the variable seems to have no strong effect on the probability of an answer. However, it has to be noted, that the patents in our final sample are characterized by a slightly lower value compared to the full sample. Furthermore, every additional inventor listed on the patent document increased the probability of an answer by 1%. This result is not surprising, since the probability of reaching an inventor increases with the available number of different inventors. Overall, there is no strong evidence of a non-response bias within the data.

<sup>5</sup> In the questionnaire, the inventors were asked the following question:

*“This is a hypothetical question. “Suppose that on the day on which this patent was granted, the applicant had all the information about the value of the patent that is available today. In case the strongest competitor of the applicant was interested in buying the patent, what would be the minimum price (in Euro) the applicant should have demanded?”* for their answers, the respondents were offered the following value categories:

*“Less than € 30.000”, “€ 30.000 to € 100.000”, “€ 100.000 to € 300.000”, “€ 300.000 to € 1 mio”, “€ 1 mio to € 3 mio”, “€ 3 mio to € 10 mio”, “€ 10 mio to € 30 mio”, “€ 30 mio to € 100 mio”, “€ 100 mio to € 300 mio”, “More than € 300 mio”.*

renewal fees. Since each additional country means additional costs, the size of the patent family can be seen as a measure of the market potential of the protected technology: the greater the market potential, the more the applicant is willing to pay for patent protection. Thus this measure reflects the investment decision made by the patent *applicant* (the firm or non-profit organization employing the inventor) based on the applicant's assessment of the value of the underlying invention (Putnam, 1996; Guellec and van Pottelsberghe, 2000). For our purposes, it has the advantage of being a continuous variable, enabling the investigation (in the form of a quantile regression) of whether or not the size of the leisure time effect on patent value increases with the value of the patent.<sup>6</sup>

Table 1 describes the operationalization of the variables and provides descriptive statistics. As explanatory variables we use indicators employed by earlier studies capturing firm-related variables (type of firm), inventor characteristics (age, education, experience), characteristics of the R&D project (size of the inventor team, incentives, sources of knowledge, financing, project size), and context specific variables (technology areas). We add a dummy variable to measure whether the underlying inventive idea occurred during the inventor's work time or leisure time.

(Table 1 about here)

Figure 1a shows a histogram of the distribution of patent value measured in terms of the inventor's assessment of the asset value of the patented invention. The shares are provided for both sub-samples (patents granted to leisure time inventions and to work time inventions) separately. Patents granted to

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<sup>6</sup> Other possible measures of patent value are less appropriate for our purposes. Patent citations – a frequently used proxy for patent value – are unsuitable for two reasons. First, patents in industries like chemicals, pharmaceuticals, biotechnology or semiconductors are more highly cited than patents from other industries. However, Davis et al. (2009) showed that patents granted to leisure time inventions occur less frequently in science based industries than in conceptual based industries. Second, citation measures are characterized by a highly skewed distribution and, at least as regards EP patents, most patents do not receive citations at all (Michel and Bettels, 2001). In our sample 56.1% of the patents have not been cited within 5 years following the publication of the search report. Thus citation counts do not allow the estimation of a quantile regression due to a lack of variation in the 0.25 and 0.5 quantiles of the citation variable. Other possible value measures, such as whether or not the patent has been opposed after grant, or subjected to legal disputes, are dummy variables, and again not appropriate for a quantile regression; moreover, the dataset does not include enough patents for which oppositions or other legal actions were filed. A final possible measure, the overall term of protection (the number of years the patent holder paid the renewal fees to maintain patent protection), while it is a continuous variable, cannot be used here because the patents in our sample were applied for in the years 1993-97, with the result that we cannot observe the full period of 20 years, the maximum term of protection.

leisure time inventions dominate the categories of high value patents (>3 mio €); the categories of low value patents (<300 T €) are dominated by work time inventions. While the value of patents granted to work time inventions follows a right-skewed distribution, the value distribution of patents on leisure time inventions is more ambiguous. Figure 1b shows a histogram of the distribution of patent value in terms of the size of the patent family. Patents granted to leisure time inventions generally dominate the categories of higher value patents (more than 10 patent family members). But the categories of lower value patents (1 to 9 patent family members) show no clear pattern. While the value of patents granted to work time inventions again follows a right-skewed distribution, the value distribution of patents on leisure time inventions is more ambiguous. The ambiguity of our findings as regards the value distribution of leisure time inventions may, at least in part, be driven by the fact that patents on work time inventions are far more common than patents granted to leisure time inventions. In our sample 6% of the patents were granted to leisure time inventions.

(Figures 1a and 1b about here)

In an effort to shed some light on what might be behind the ambiguous distribution of patent values in Figure 1b, we performed a Chi2 test of the characteristics of the most valuable (top 25%), and least valuable (bottom 25%), patents in our sample – including both leisure time and work time inventions – measured in terms of the size of the patent family. Table 2 summarizes these results, using the explanatory variables presented in Table 1. First, comparing the characteristics of the most valuable patents on both leisure time and work time inventions (columns 3 and 4), we can see that the most valuable patents on leisure time inventions were granted to inventions that are significantly (at the 1% level) less likely to be made by an inventor working for a firm (that is, the inventor is more likely to be working for a university or a government research organization), less likely refer to a science based problem, and more likely to refer to a conceptual-based problem. The 25% most valuable patents granted to leisure time inventions, compared with the 25% least valuable patents granted to leisure time inventions (columns 3 and 1) are significantly (at the 1% level) more likely to protect conceptual-based inventions (and less likely medium science-based inventions). They are also less likely to protect inventions made by an inventor working for

a firm, more likely to protect inventions made by an inventor who earned a doctoral or a postdoctoral degree, more likely to protect inventions that draw on earlier patents as knowledge sources, and, finally, more likely to protect inventions that are made in a large project (all significant at 5%). Overall, this indicates that there does seem to be a relationship between the characteristics of the leisure time creative process and the value of the resulting patent.

(Table 2 about here)

### 3 Method and results

For our multivariate analysis, we first use an ordered probit model (dependent variable: asset value of the patents) and an OLS regression model (dependent variable: patent family size) to analyze the effect of leisure time inventive activity on patent value. Second, to learn more about the gains from leisure time inspiration, a quantile regression is employed. While the OLS model estimates the impact of the explanatory variables at the conditional mean of the dependent variable, quantile regression allows us to estimate the impact of our continuous explanatory variable, the size of the patent family, at different points of the conditional distribution of the dependent variable (Koenker and Bassett, 1978; Eide and Showalter, 1999).

The following quantile regression model is estimated:

$$Q_{\theta}(y|x) = \gamma_{\theta,0} + \gamma_{\theta,1} * d\_leisure + \sum_i \gamma_{\theta,i} * controls_i$$

where  $Q_{\theta}(y|x)$  denotes the  $\theta$ th conditional quantile of  $y$  given  $x$ . The model is estimated at the 0.5 and 0.75 quantiles.

These findings are provided in Table 3. Model 1 displays the results of an ordered probit regression model using the asset value as the dependent variable. The coefficients of the explanatory variables exhibit the expected signs and confirm earlier results provided in the literature.

(Table 3 about here)

In Model 2, we add the leisure time dummy as an explanatory variable. Results show that the effect of leisure time on the asset value of the patents is positive and highly significant. Model 3 provides an OLS regression using patent family size as a dependent variable. Again leisure time has a positive and significant effect. To learn more about the gains from leisure time inventive activity, we used the coefficients of Model 3 (dependent variable: patent family size) to predict patent value and compared the mean of the predicted values of patent value with the mean value of the patents granted to leisure time inventions in our sample. Results show that the average value of the patents on leisure time inventions, which amounts to 8.32, exceeds the average value of the predicted patent value, i.e. 7.74. This finding provides a further strong indication of the importance of leisure time invention for the value of the patents on the resulting inventions.

Finally, Model 4 provides the results of the quantile regression. Again, we use the size of the patent family as the dependent variable. Results show not only that the effect of leisure time is always positive and significant, but that the effect also increases with the value of the patent. More specifically, the size of the coefficient increases by one third between the 0.5 and the 0.75 quantile.

## **4 Concluding Remarks**

### **4.1 Limitations**

In interpreting the results of this study, certain limitations have to be kept in mind. First, as with prior studies of inventive activity, our survey is based on patent data, which provides an incomplete coverage of innovative activity, since not all inventions are patented or patentable (Cohen et al. 2000). Consequently, our dataset does not permit a complete understanding of the economic value of leisure time inventive activity. Second, as pointed out above, leisure time inventive activity is infrequently observed; the share of patents granted to leisure time inventions amount to only 6%. An increase in the overall sample, leading to a higher absolute number of patents granted to leisure time inventions, should support a more rigorous, multivariate analysis of the determinants of the value of the patents on leisure time and work time inventions,

respectively. We also find it important to develop a better understanding of what might be unique about the problem-solving process during leisure time – and by extension, what theories would be appropriate to structure the analysis of the determinants of the value of leisure time inventions. In future work, we plan to delve more deeply into the reasons why patents granted to leisure time inventions might be more valuable, both by conducting personal interviews with the inventors concerned, and by testing additional data, which we are currently collecting.

#### **4.2 Summary and Implications**

Overall, our results provide the first evidence for the positive effects of leisure time activities on patent value. This suggests that there is a jointness between creativity on the job, and creativity during inventor leisure time. Three possible implications of this jointness might be highlighted. First, studies have shown that corporate programs that give highly pressured employees the opportunity for unstructured free time do not necessarily achieve their goals of enhancing creative performance (Elsbach and Hardagon, 2006). Perhaps what makes the leisure time inventor “different” is simply that, by engaging in *unpaid* work, she is less constrained by (or vulnerable to the negative effects of) job-related stress and ways of thinking – and thereby more receptive to the proverbial “flash of genius”. In one sense, our results can be said to support Elsbach and Hardagon’s proposal of allowing employees to engage in “mindless” tasks at work – to the extent that these workers perceive such tasks as unrelated to their paid employment. But if employees view such tasks as part of their paid work, the proposal may not be effective.

Second, further research could analyze the relationship between the value of leisure time invention and the nature of the inventor’s leisure time hobbies. Sherwood (2006) argues that it may be possible to identify how creative inventors are by asking them about their hobbies. While this conclusion has not yet been scientifically tested, some employers are already arguing that hobbyist employees are best assigned to workplace R&D and product development teams. Hobbies like developing computer games or restoring

antique automobiles may thus lead to insightful combinations, both at the workplace and at home.<sup>7</sup> Such inventions may not necessarily lead to higher value patents in themselves. But if hobbyists perform better in creative work tasks than their peers, their leisure time inventions would yield patents of greater value.

Finally, since some of the patents granted to leisure time inventive breakthroughs can be more valuable than those for work time inventions, it would be interesting to explore how managers can best realize the potential benefits from employee leisure time activities. On the one hand, managers might wish to encourage creativity in their employees (and to bring their leisure time insights to create value in the workplace). On the other, managers must ensure that creativity leads to performance results. Future work could provide managers with more tools to distinguish between what is valuable about leisure time inventive activity, and what is not, so as better to incorporate leisure time insights into their overall innovation efforts.

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<sup>7</sup> Particularly important hobbies related to creativity are those requiring cognitive input and practice. Playing an instrument, writing poetry, carpentry, building electronic devices, and computer programming are examples of hobbies which impact positively on creative talent (Hong *et al.*, 1993).

## References

- Amabile, T.M., R. Conti, H. Coon, J. Lazenby, M. Herron. 1996. Assessing the Work Environment for Creativity. *Academy of Management Journal*. 39(5) 1154-1184.
- Åstebro, T. 2003. The Return to Independent invention: Evidence of Unrealistic Optimism, Risk Seeking or Skewness Loving? *The Economic Journal*. 113, pp. 226-239.
- Bittman, M. / Wajcman, J.(2000) The Rush Hour: The Character of Leisure Time and Gender Equity, *Social Forces*, 79(1), pp. 165-189.
- Cohen, W.M. /Nelson, R.R. / Walsh, J.P. (2000). Protecting Their Intellectual Assets: Appropriability Conditions and Why U. S. Manufacturing Firms Patent (or Not), NBER, Working Paper, 7552, Cambridge, Mass.
- Dahlin, K. / Taylor, M. / Fichman, M. (2004). Today's Edisons or Weekend Hobbyists: Technical Merit and Success of Invention by Independent Inventors, *Research Policy*, 33(8), pp. 1167-1183.
- Davis, L.N. / Davis, J. / Hoisl, K. (2009). What Inspires Leisure Time Invention? *Paper presented to the DRUID Conference*, Copenhagen, Denmark (June).
- Eide, E.R. / Showalter, M.H. (1999). Factors Affecting the Transmission of Earnings across Generations: A Quantile Regression Approach, *The Journal of Human Resources*, 34(2), pp. 253-267.
- Elsbach, K.D. / Hargadon, A.B. (2006). Enhancing Creativity Through "Mindless" Work: A Framework of Workday Design, *Organization Science*, 17(4), pp. 470-483.
- Fleming, L. 2006. Lone Inventors are the Source of Technological Breakthroughs; Myth or Reality?. *HBS Working Paper*, Harvard Business School, Boston, MA.
- Fleming, L., O. Sorenson. 2004. Science as a Map in Technological Search, *Strategic Management Journal*, 25(8/9), pp. 909-928.
- Gambardella, A. / Harhoff, D. / Verspagen, B. (2008). The Value of Patents, *Discussion Paper*, presented at the Conference on the Economics of Competition and Innovation, October 26-27, 2007, University of California at Berkeley, CA.
- Goodin, Robert E.; Rice, James Mahmud; Bittman, Michael; & Saunders, Peter. (2005). "The time-pressure illusion: Discretionary time vs free time". *Social Indicators Research* 73 (1), 43-70.
- Guellec, D. / van Pottelsberghe de la Potterie, B. (2000). Applications, Grants and the Value of Patent, *Economic Letters*, 69(1), pp. 109-114.
- Hackman, J.R. / Oldham, G.R. (1980). *Work Redesign*, Addison-Wesley, Reading, MA.
- Harhoff, D. / Hoisl, K. (2007). Institutionalized Incentives for Ingenuity - Patent Value and the German Employees' Invention Act, in: *Research Policy*, 36(8), pp. 1143-1162.
- Harhoff, D. / Narin, F. / Scherer, F.M. / Vopel, K. (1999). *Citation Frequency and the Value of Patented Inventions*, *The Review of Economics and Statistics*, 83, No. 3, pp. 511-515.
- Harhoff, D. / Scherer, F.M. / Vopel, K. (2003). Citations, Family Size, Opposition and the Value of Patent Rights - Evidence from Germany, *Research Policy*, 32, pp. 1343-1363.

- Harhoff, D. / Reitzig, M. (2004). *Determinants of Opposition against EPO Patent Grants – The Case of Biotechnology and Pharmaceuticals*, *International Journal of Industrial Organization*, 22, pp. 443-480.
- Heinsohn, R.J. 2007. *The Wright Brothers and William Brewster*, available at [www.sail1620.org/discover/feature\\_the\\_wright\\_brothers\\_and\\_william\\_brewster.html](http://www.sail1620.org/discover/feature_the_wright_brothers_and_william_brewster.html), accessed February 13, 2007.
- Hoisl, K. (2007). Tracing Mobile Inventors - The Causality between Inventor Mobility and Inventor Productivity. *Research Policy*. 36(5), pp. 619-636.
- Hong, E. / Milgram, R.M. / Whiston, S.C. (1993). Leisure Activities in Adolescence as a Predictor of Occupational Choice in Young Adults: A Longitudinal Study, *Journal of Career Development*, 19, pp. 221-229.
- Koenker, R. / Bassett, G. (1978). Regression Quantiles, *Econometrica*, 46(1), pp. 33-50.
- Kogut, B. / Zander, U. (1992). Knowledge of the firm, combinative capabilities, and the replication of technology, *Organization Science*, 3(3), pp. 383–397.
- Lanjouw, J.O. / Pakes, A. / Putnam, J. (1998). How to Count Patents and Value Intellectual Property. The Use of Patent and Renewal and Application Data, *The Journal of Industrial Economics*, 46(4), pp. 405-433.
- Lanjouw, J.O. / Schankerman, M. (2001). Enforcing Intellectual Property Rights, *NBER Working Paper No. 8656*, Cambridge, Mass.
- Lerner, J. (1994). The importance of patent scope: An empirical analysis, *Rand Journal of Economics*, 25(2), pp. 319-333.
- Markides, C.C. / Geroski, P.A. (2004). *Fast Second*, San Francisco: Wiley.
- Michel, J. / Bettels, B. (2001). Patent Citation Analysis – A Closer Look at the Basic Input Data from Patent Search Reports, *Scientometrics*, 51(1), pp. 185-201.
- Nelson, R.R. 1959. The Economics of Invention: A Survey of the Literature. *The Journal of Business*. 32(2) 101-127.
- OECD (1994). *Using Patent Data as Science and Technological Indicators – Patent Manual 1994*, Paris.
- Oldham, G.R. (2003). Stimulating and Supporting Creativity in organizations. In: S.E. Jackson, M.A. Hitt, A.S. DeNisi (eds.): *Managing Knowledge for Sustained Competitive Advantage*, Jossey-Bass, San Francisco, CA, pp. 243-273.
- Pakes, A. (1986). Patents as Options. Some Estimates of the Value of Holding European Patent Stocks, *Econometrica*, 54(4), pp. 755-784.
- Putnam, J. (1996). *The Value of International Patent Rights*. Yale.
- Robinson, J.P. / Godbey, G. (1990). *Time for Life: The Surprising Ways Americans Use Their Time*. State College, Penna: Penn State Press.

- Rosenberg, N. (1994). *Exploring the Black Box: Technology Economics and History*. Cambridge University Press, New York.
- Rosenkopf, L. / Nerkar, A. (2001). Beyond local search: Boundary-spanning, exploration, and impact in the optical disk industry, *Strategic Management Journal*, 22, pp. 287-306.
- Schankerman, M. / Pakes, A. (1986). Estimates of the Value of Patent Rights in European Countries - During the Post-1950 Period, *Economic Journal*, 96(384), pp. 1052-1076.
- Shalley, C.E., J. Zhou, G.R. Oldham. 2004. The Effects of Personal and Contextual Characteristics on Creativity: Where should we Go from Here?. *Journal of Management*. 30(6) 933-958.
- Sherwood, B. (2006). Innovation: Do I need it? Do I have it? Can I get it? *Metal Finishing*, 104(11), November, p.55.
- Tong, X. / Frame, J.D. (1992). Measuring National Technology Performance with Patent Claims Data, *Research Policy*, 23, pp. 133-141.
- Zhou, J. / Shalley, C. (eds.) (2008). *Handbook of Organizational Creativity*. Taylor and Francis, New York.

| Variable name                           | Description of the variables  | Mean  | Std. Dev. | Min | Max |
|---|---|-------|-----------|-----|-----|
| asset value of the patents              | question: "Suppose that on the day of the grant of this patent, the applicant had all the information about the value of the patent that is available today. In case the strongest competitor of the applicant was interested in buying the patent, what minimum price should the applicant have demanded?" | 3*    |           | 1♦  | 6   |
| patent family size                      | all patent documents having at least one priority in common   | 7.77  | 3.94      | 1   | 18  |
| leisure time invention                  | dummy variable capturing whether the idea for the invention came up during the inventor's leisure time or work time   | 0.06  |           | 0   | 1   |
| type of the organization: firm          | dummy variable indicating the type of organization the inventor is employed with. 1: inventor is employed with a firm and 0: the inventor works for a public or a private research institute or for a university  | 0.95  |           | 0   | 1   |
| age of the inventor                     | age of the inventor at the time of the survey   | 49.78 | 9.64      | 24  | 80  |
| level of education                      | highest attained educational degree   |       |           |     |     |
| high school diploma or less             |   | 0.13  |           | 0   | 1   |
| university studies                      |   | 0.54  |           | 0   | 1   |
| doctoral/post doctoral studies          |   | 0.33  |           | 0   | 1   |
| number of inventions (1 year prior)     | number of other patent applications listing the name of the inventors during the one year period prior to the date of the patent application under consideration  | 3.19  | 3.49      | 1   | 33  |
| motivation                              | dummy variables capturing the importance of different types of rewards for making the invention   |       |           |     |     |
| extrinsic mot. (salary increase)        | extrinsic reward: "increase in salary"  | 0.67  |           | 0   | 1   |
| extrinsic mot. (advancement)            | extrinsic reward: "job advancement"   | 0.59  |           | 0   | 1   |
| intrinsic mot. (reputation)             | intrinsic reward: "prestige/reputation"   | 0.47  |           | 0   | 1   |
| type of interaction                     | importance of meetings or discussions with people from other organizations (apart from the co-inventors listed on the patent) during the research process leading to the invention  |       |           |     |     |
| other organization (distance <= 1 hour) | people from other organizations who can be reached in less than one hour  | 0.12  |           | 0   | 1   |
| other organization (distance > 1 hour)  | people from other organizations who can be reached in more than one hour  | 0.24  |           | 0   | 1   |
| knowledge sources                       | dummy capturing the importance of different sources of external knowledge for the development of an invention   |       |           |     |     |
| scientific literature                   |   | 0.64  |           | 0   | 1   |
| university research                     |   | 0.25  |           | 0   | 1   |
| patent documents                        |   | 0.66  |           | 0   | 1   |
| users                                   |   | 0.75  |           | 0   | 1   |
| size of the inventor team               | number of inventors listed on the patent document, used as a proxy for the size of the inventor team  | 2.84  | 1.90      | 1   | 16  |
| financial resources: internal funds     | dummy variable capturing whether the research leading to the patented invention was funded by the applicant's internal sources, or by external sources (e.g., unaffiliated organizations, government, or financial intermediaries)  | 0.96  |           | 0   | 1   |
| project size                            | total labor input needed  |       |           |     |     |
| small project                           | labor input: less than 4 man-months   | 0.49  |           | 0   | 1   |
| medium sized project                    | labor input: 4-12 man-months  | 0.34  |           | 0   | 1   |
| large project                           | labor input: more than 12 man-months  | 0.09  |           | 0   | 1   |
| type of problem                         | IPC class to which the European Patent Office assigned the invention were used as a proxy for the type of problem   |       |           |     |     |
| science based problem                   | inventions assigned to chemicals and pharmaceuticals  | 0.24  |           | 0   | 1   |
| medium science based problem            | inventions assigned to electricity/electronics and mechanical engineering   | 0.39  |           | 0   | 1   |
| conceptual based problem                | inventions assigned to instruments, process engineering, and consumer goods/civil engineering   | 0.37  |           | 0   | 1   |

\* mean / ♦ 1 = "less than €30T", 2 = "€30T - €100T", 3 = "€100T - €300T", 4 = "€300T - €1 mio.", 5 = "€1 mio. - €3 mio.", 6 = "€3 mio. - €10 mio.", 7 = "above €10 mio."

**Table 1:** Descriptive statistics (N = 2,435)

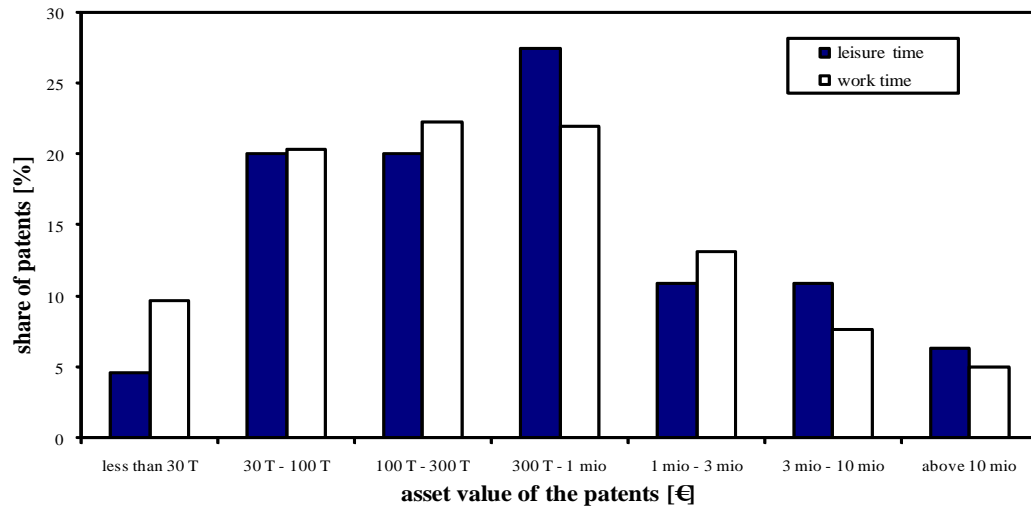


Figure 1a: Asset value of the patents (N = 2,435)

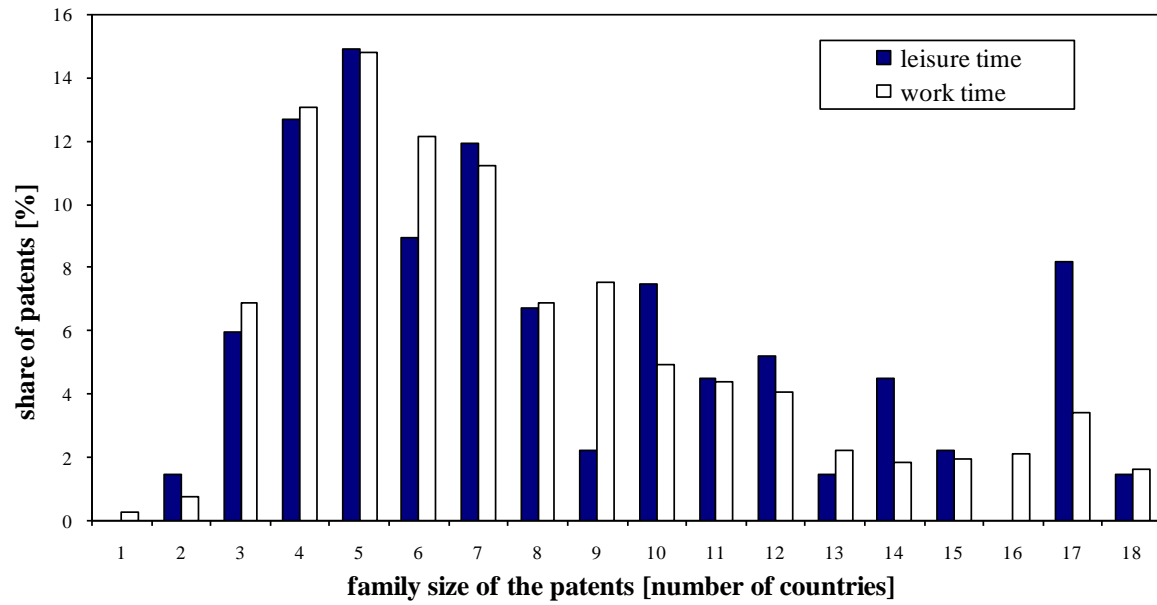


Figure 1b: Family size of the patents (N = 2,435)

|   | N <sub>1</sub> = 47 | N <sub>2</sub> = 823 | N <sub>3</sub> = 47 | N <sub>4</sub> = 609 |                                   |                                     |                                     |
|---|---------------------|----------------------|---------------------|----------------------|-----------------------------------|-------------------------------------|-------------------------------------|
| <b>GROUP</b>                            | <b>1</b>            | <b>2</b>             | <b>3</b>            | <b>4</b>             | Chi2-<br>test:<br>all 4<br>groups | Chi2-<br>test:<br>groups<br>3 and 4 | Chi2-<br>test:<br>groups<br>1 and 3 |
| <b>type of invention</b>                | leisure<br>time     | work<br>time         | leisure<br>time     | work<br>time         |                                   |                                     |                                     |
| <b>size of the patent family</b>        | <b>bottom 25%</b>   |                      | <b>top 25%</b>      |                      |                                   |                                     |                                     |
|   | Mean                | Mean                 | Mean                | Mean                 |                                   |                                     |                                     |
| type of the organization: firm          | 0,96                | 0,96                 | 0,83                | 0,95                 | ***                               | ***                                 | **                                  |
| age of the inventor                     | 52,53               | 49,47                | 51,32               | 49,89                |                                   |                                     |                                     |
| level of education                      |                     |                      |                     |                      |                                   |                                     |                                     |
| high school diploma or less             | 0,30                | 0,10                 | 0,17                | 0,14                 | ***                               |                                     |                                     |
| university studies                      | 0,57                | 0,61                 | 0,53                | 0,45                 | ***                               |                                     |                                     |
| doctoral/post doctoral studies          | 0,13                | 0,28                 | 0,30                | 0,41                 | ***                               |                                     | **                                  |
| number of inventions (1 year prior)     | 3,04                | 3,14                 | 2,89                | 3,26                 |                                   |                                     |                                     |
| motivation                              |                     |                      |                     |                      |                                   |                                     |                                     |
| extrinsic motivation (salary increase)  | 0,68                | 0,69                 | 0,64                | 0,69                 |                                   |                                     |                                     |
| extrinsic motivation (advancement)      | 0,57                | 0,61                 | 0,51                | 0,60                 |                                   |                                     |                                     |
| intrinsic motivation (reputation)       | 0,47                | 0,45                 | 0,49                | 0,47                 |                                   |                                     |                                     |
| type of interaction                     |                     |                      |                     |                      |                                   |                                     |                                     |
| other organization (distance <= 1 hour) | 0,11                | 0,12                 | 0,23                | 0,13                 |                                   | *                                   | *                                   |
| other organization (distance > 1 hour)  | 0,26                | 0,21                 | 0,30                | 0,29                 | ***                               |                                     |                                     |
| knowledge sources                       |                     |                      |                     |                      |                                   |                                     |                                     |
| scientific literature                   | 0,43                | 0,62                 | 0,57                | 0,67                 | ***                               |                                     |                                     |
| university research                     | 0,13                | 0,23                 | 0,28                | 0,29                 | **                                |                                     | *                                   |
| patent documents                        | 0,40                | 0,64                 | 0,66                | 0,67                 | ***                               |                                     | **                                  |
| users                                   | 0,70                | 0,74                 | 0,83                | 0,77                 |                                   |                                     |                                     |
| size of the inventor team               | 2,23                | 2,71                 | 2,49                | 3,14                 |                                   |                                     |                                     |
| financial resources: internal funds     | 0,83                | 0,95                 | 0,91                | 0,97                 | ***                               | *                                   |                                     |
| project size                            |                     |                      |                     |                      |                                   |                                     |                                     |
| small project                           | 0,68                | 0,53                 | 0,51                | 0,42                 | ***                               |                                     | *                                   |
| medium sized project                    | 0,26                | 0,32                 | 0,36                | 0,37                 | *                                 |                                     |                                     |
| large project                           | 0,00                | 0,08                 | 0,09                | 0,12                 | ***                               |                                     | **                                  |
| type of problem                         |                     |                      |                     |                      |                                   |                                     |                                     |
| science based problem                   | 0,09                | 0,15                 | 0,13                | 0,34                 | ***                               | ***                                 |                                     |
| medium science based problem            | 0,57                | 0,53                 | 0,26                | 0,27                 | ***                               |                                     | ***                                 |
| conceptual based problem                | 0,34                | 0,32                 | 0,62                | 0,39                 | ***                               | ***                                 | ***                                 |

In a Chi2-Test, the difference between leisure time and work time inventions turned out to be significant (\* significant at 10%; \*\* significant at 5%; \*\*\* significant at 1% )

**Table 2:** Chi2-Test (differences between leisure time and work time inventions)

|   | Model 1                    | Model 2              | Model 3                   | Model 4a                                | Model 4b             |
|---|----------------------------|----------------------|---------------------------|---|----------------------|
|   | Ordered Probit             | Ordered Probit       | OLS                       | Quantile Regression (jointly estimated) |                      |
|   |                            |                      |                           | 0.5                                     | 0.75                 |
| dependent variable  | asset value of the patents |                      | size of the patent family |   |                      |
| leisure time invention (dummy)                                    |                            | 0.310***<br>[0.088]  | 0.679*<br>[0.366]         | 0.755**<br>[0.324]                      | 1.263***<br>[0.826]  |
| type of the organization: firm                                    | -0.277***<br>[0.088]       | -0.265***<br>[0.088] | -0.777*<br>[0.415]        | -1.807***<br>[0.588]                    | -1.056**<br>[0.601]  |
| age of the inventor   | 0.005**<br>[0.002]         | 0.005**<br>[0.002]   | 0.002<br>[0.009]          | 0.002<br>[0.009]                        | 0.031***<br>[0.015]  |
| level of education (reference group: high school diploma or less) |                            |                      |                           |   |                      |
| university studies  | 0.042<br>[0.065]           | 0.054<br>[0.066]     | -0.682***<br>[0.258]      | -0.311<br>[0.278]                       | -1.405***<br>[0.493] |
| doctoral/post doctoral studies                                    | 0.001<br>[0.076]           | 0.016<br>[0.076]     | -0.507*<br>[0.296]        | 0.021<br>[0.252]                        | -0.935<br>[0.550]    |
| number of inventions (1 year prior)                               | 0.001<br>[0.007]           | 0.0005<br>[0.007]    | -0.036*<br>[0.021]        | -0.028**<br>[0.015]                     | -0.093***<br>[0.049] |
| motivation  |                            |                      |                           |   |                      |
| extrinsic motivation (salary increase)                            | -0.033<br>[0.054]          | -0.034<br>[0.054]    | 0.242<br>[0.193]          | 0.346<br>[0.200]                        | 0.495<br>[0.373]     |
| extrinsic motivation (advancement)                                | 0.179***<br>[0.052]        | 0.177***<br>[0.052]  | -0.091<br>[0.191]         | -0.308<br>[0.235]                       | -0.010<br>[0.417]    |
| intrinsic motivation (reputation)                                 | 0.154***<br>[0.043]        | 0.155***<br>[0.043]  | 0.057<br>[0.161]          | -0.042<br>[0.152]                       | -0.044<br>[0.279]    |
| type of interaction   |                            |                      |                           |   |                      |
| other organization (distance <= 1 hour)                           | 0.097<br>[0.071]           | 0.092<br>[0.071]     | 0.305<br>[0.271]          | 0.214<br>[0.270]                        | 1.045<br>[0.601]     |
| other organization (distance > 1 hour)                            | 0.063<br>[0.053]           | 0.062<br>[0.053]     | 0.642***<br>[0.203]       | 0.272<br>[0.225]                        | 1.603***<br>[0.472]  |
| knowledge sources   |                            |                      |                           |   |                      |
| scientific literature   | 0.043<br>[0.049]           | 0.047<br>[0.049]     | -0.138<br>[0.182]         | 0.087<br>[0.123]                        | -0.153<br>[0.379]    |
| university research   | 0.125**<br>[0.053]         | 0.123**<br>[0.053]   | 0.382*<br>[0.196]         | 0.241<br>[0.165]                        | 0.838**<br>[0.439]   |
| patent documents  | -0.021<br>[0.050]          | -0.021<br>[0.050]    | -0.353*<br>[0.184]        | -0.379**<br>[0.225]                     | -0.786**<br>[0.354]  |
| users   | 0.107**<br>[0.053]         | 0.108**<br>[0.053]   | 0.173<br>[0.187]          | 0.236<br>[0.204]                        | 0.099<br>[0.351]     |
| size of the inventor team   | -0.008<br>[0.012]          | -0.007<br>[0.012]    | 0.135***<br>[0.046]       | 0.058<br>[0.070]                        | 0.207*<br>[0.110]    |
| financial resources: internal funds                               | 0.001<br>[0.104]           | 0.025<br>[0.103]     | 0.111<br>[0.407]          | 0.557<br>[0.363]                        | -0.056<br>[0.727]    |
| project size (reference group: small project)                     |                            |                      |                           |   |                      |
| medium sized project  | 0.189***<br>[0.046]        | 0.193***<br>[0.046]  | 0.040<br>[0.170]          | 0.123<br>[0.178]                        | 0.310<br>[0.339]     |
| large project   | 0.404***<br>[0.075]        | 0.417***<br>[0.075]  | 0.848***<br>[0.302]       | 0.962***<br>[0.307]                     | 1.488*<br>[0.971]    |
| type of problem (reference group: science based problem)          |                            |                      |                           |   |                      |
| medium science based problem                                      | -0.125*<br>[0.066]         | -0.127*<br>[0.066]   | -2.042***<br>[0.243]      | -2.115***<br>[0.257]                    | -2.741***<br>[0.437] |
| conceptual based problem  | -0.131**<br>[0.063]        | -0.139**<br>[0.064]  | -0.892***<br>[0.248]      | -0.877***<br>[0.295]                    | -1.043*<br>[0.530]   |
| Constant  |                            |                      | 9.342***<br>[0.834]       | 8.756***<br>[0.934]                     | 10.803***<br>[1.464] |
| Observations  | 2435                       | 2435                 | 2435                      | 2435                                    | 2435                 |
| R-squared   |                            |                      | 0.073                     |   |                      |
| Pseudo R-squared  | 0.016                      | 0.017                |                           | 0.047                                   | 0.055                |

Models 1 to 3: Robust standard errors in brackets / Models 4a and 4b: Bootstrap standard errors in brackets

\* significant at 10%; \*\* significant at 5%; \*\*\* significant at 1%

**Table 3:** Ordered probit, OLS, and jointly estimated quantile regression  
(dependent variable: asset patent value and size of the patent family)