Spanning the Creative Space between Home and Work

Leisure Time, Hobbies and Organizational Creativity

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Abstract

This paper explores the link between employee leisure time activities and the value of their creative output. We argue that leisure time activities ? both in general, and specifically with regard to the employee?s choice of hobbies ? both illuminate and shape the attitudes and attributes the employee brings to work. Based on Woodman et al.?s (1993) ?interactionist perspective? on organizational creativity, supplemented by literature on search and knowledge re/combination, we explore whether leisure time activities can span the creative space between the employee?s home and workplace ? given the range of multi-level inputs that may also contribute to workplace creativity. We use original survey data comprising 4,138 inventions from 21 European countries, the United States and Japan, in all major industries. Organizational creativity is measured by the asset value of the patent on the associated invention, and the degree of radicalness of the invention. We find that employees who continue to think about their workplace research while away from work produce more valuable inventions. Diversity of hobbies, more socially oriented hobbies, and more focused hobbies are also positively related to invention value.

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ABSTRACT

This paper explores the link between employee leisure time activities and the value of their creative output. We argue that leisure time activities – both in general, and specifically with regard to the employee's choice of hobbies – both illuminate and shape the attitudes and attributes the employee brings to work. Based on Woodman et al.'s (1993) "interactionist perspective" on organizational creativity, supplemented by literature on search and knowledge re/combination, we explore whether leisure time activities can span the creative space between the employee's home and workplace – given the range of multi-level inputs that may also contribute to workplace creativity. We use original survey data comprising 4,138 inventions from 21 European countries, the United States and Japan, in all major industries. Organizational creativity is measured by the asset value of the patent on the associated invention, and the degree of radicalness of the invention. We find that employees who continue to think about their workplace research while away from work produce more valuable inventions. Diversity of hobbies, more socially oriented hobbies, and more focused hobbies are also positively related to invention value.

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"The only insult I've ever received in my adult life was when someone asked me, 'Do you have a hobby?' A HOBBY?! DO I LOOK LIKE A [expletive deleted] DABBLER?!"

(quoted in Waters, 2011)

INTRODUCTION

The literature on organizational creativity widely agrees that individual employee characteristics play an important role in organizational innovation (Woodman et al. 1993, Oldham and Cummings 1996, Bharadwaj and Menon 2000). Amabile et al. (1996: 1155) refer to individual creativity "the seed of all innovation". While the effects of personal characteristics like experience, education, or motivation on organizational creativity (e.g., Amabile at el. 1996, Amabile 1983, Amabile 1998, Woodman et al. 1993, Oldham and Cummings 1996) have extensively been explored, no empirical studies, to our knowledge, have analyzed how employee leisure time activities can contribute to creative organizational output.

We argue that leisure time activities – both in general, and specifically with regard to the employee's choice of hobbies – illuminate and shape the attitudes and attributes the employee brings to work. We base our analysis on Woodman et al.'s (1993) "interactionist perspective" on organizational creativity, supplemented by literature on search and knowledge re/combination (e.g. Fleming and Sorensen 2004). Our research question asks: What is the relationship between employee leisure time activities and the value of their creative output?

While many observers (such as Waters in the quote above), see leisure time pursuits like hobbies as a waste of time, pursued by "dabblers", studies suggest that hobbyists can play an important role in invention and innovation (Dahlin et al. 2004). Hobbyists have been responsible for major advances in open source innovation (Lakhani and Wolf 2005), served as respondents in broadcast search (Jeppesen and Lakhani 2010), and as a source of user innovations (von Hippel 1988). De Jong et al. (2010), for example, in a representative UK survey, found that in the previous three years, 6.2% (2.9 million individuals) of users of consumer products were responsible for household sector innovation involving the development and modification of these products. Many user inventions were made by people during their leisure time.

There is some evidence that the pursuit of hobbies might affect creativity (Barron and Harrington, 1981). Certain biographical studies link leisure time pursuits to scientific and artistic creativity (e.g. Simonton 1975, 1984, Singh 1986, Woodman and Schoenfeldt 1989, Root-Bernstein and Bernstein 1995). Wolfradt and Pretz (2001) use personal hobby choice as a measure of creativity. Related work investigates the impact of leisure time *per se* on employee performance (Madjar et. al. 2002). Some managers use employee hobbies to influence personnel policies.[1] But scholarship on the link between leisure time activities and work place creativity is inconclusive.

We believe that hobbies can support workplace creativity in three major ways: First, employee inventors may be able to use skills developed while pursuing a hobby – such as a disciplined approach to problem-solving – to address problems at work (Kotro 2007). Second, they may have access to external knowledge sources that may not be available during work time (Granovetter 1973, 1983) and that may be combined with workplace knowledge to produce valuable inventions. Third, employees may benefit indirectly from hobbies, since leisure time activities have been shown to play an important role in the development of cognitive skills (Singh-Manoux et al. 2003). This should particularly be the case for two cognitive skills: an ability to analogize, and the capacity to engage in divergent thinking (Brunswicker and Hutschek 2010).

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[1] For example, the director of Sherwood Business Management Corporation advises his readers in ***Metal Finishing*** magazine: “Discover the most creative individuals by asking them about their hobbies. High on the list are painting, antique car refurbishing, interior decorating, handicrafts and model making. Down at the bottom are beer drinking TV watching and spectator sports. Give the high-end people special projects to work on. Encourage the low-end people despite the indicated minimum potential” (Sherwood, 2006: 55).

Hobbies are defined as activities “done regularly in one’s leisure time for pleasure” (Oxford Dictionary, 2013). They are especially promising to analyze with respect to work time creativity, as they are uniquely different from, yet similar to, work-time tasks. There is no boss to tell the employee when, where, or how to engage in a hobby. But hobbies are also regularly pursued, involve an effort, and require certain skills – which can also be brought to bear at the workplace. After all, the employee is the same person, whether at work or play. What is critical is that while hobby-related skills were developed (and exist) separately from the workplace, they may also enrich workplace creativity.

While the above arguments may hold for employees of any specialization, they should have special relevance for “knowledge workers”: scientists, engineers and other creative individuals engaged in development of new processes, products or technologies. Inventors – operationalized in this paper as individuals who contributed to European patent applications – can be considered an important subgroup of knowledge workers. A study of inventor leisure time activities should be particularly telling to explain the emergence of valuable innovation output.

We base our analysis on original survey data comprising 4,138 inventions from 21 European countries, the United States and Japan, in all major industries. These responses were matched with comprehensive register information about patents filed at the European Patent Office (EPO). The survey covered both the inputs to creativity, including the inventor’s choice of hobbies, and the value of the resulting invention, measured both in terms of “asset value” (indicating the overall commercial importance of the invention), and “inventive step" (indicating the degree of radicalness of the underlying technology).

We consider the effects of leisure time activities both generally, and in terms of the number and types of employee leisure time hobbies. We find that employees who continue to think about their workplace research while away from work produce more valuable inventions. Diversity of hobbies, more socially oriented hobbies (where other people are typically involved in carrying out the hobby), and more focused hobbies (where the hobby has a well-defined goal) are also positively related to invention value. But the type of value created is different. As we will demonstrate, certain types of hobbies are positively related to asset value but not inventive step, while others are positively related to inventive step but not asset value.

While other scholars have explored particular aspects of how leisure time activities can affect creativity (e.g. Dahlin et al. 2004, Lakhani and Wolf 2005, Jeppesen and Lakhani 2010, Von Hippel 1988, De Jong et al 2010, Barrington and Harrington 1981, Madjar et al 2002), our paper is the first, as far as we are aware, to address this issue within a multi-level framework controlling for possible effects of other individual characteristics, group characteristics and organizational characteristics, as conceptualized by Woodman et al. (1993). By combining Woodman et al.'s (1993) interactionist perspective with literature on search and knowledge re/combination, we seek to obtain a more nuanced understanding of how employee leisure time activities can contribute to the value of the associated invention. Since we break down the concept of invention value into two components – asset value and inventive step – we also contribute to the understanding of how the impact of individual employee characteristics on creativity can differ. Finally, the paper provides practical implications for R&D and human resource management by shedding more light into the determinants of productivity-enhancing hires.

THEORETICAL BACKGROUND AND HYPOTHESES

In Woodman et al.'s (1993) interactionist framework, the individual employee's contribution to organizational creativity is defined in terms of four factors: cognitive abilities/style (like fluency, the ability to combine divergent and convergent thinking, problem-solving); personality (broad interests, energy, curiosity, an internal locus of control); intrinsic motivation (where creativity is motivated inherent interest as opposed to monetary/career rewards), and knowledge (technical skills, talent, previous experience). These factors interact in complex ways with group factors (like norms, roles, and tasks) and organizational factors (like culture, resources, strategy). They are transformed, through internal creative processes, to generate the output: organizational creativity, defined as "the creation of a valuable, useful, new product service, idea, procedure, or process by individuals working together in a complex social system" (Woodman et al. 1993: 293).

Given that our focus is knowledge workers, the Woodman et al. (1993) framework should, in our view, be supplemented by literature on the determinants of invention value, particularly studies of search and knowledge sourcing (e.g. Fleming 2001, Fleming and Sorenson, 2001, 2004). Inventions are defined as either "a synthesis of existing and/or new technological components or a refinement of a previous combination of technologies" (Fleming 2001: 117). We propose that leisure time activities in general, and hobbies in particular, can contribute to the individual employee's ability to engage in valuable search and knowledge recombination:

We conceptualize hobbies as both antecedents to, and reflections of, three of the four individual factors specified by Woodman et al. (1993): cognitive abilities/style, personality, and knowledge. [2] We believe that the inventor should be able to transfer the kinds of cognitive skills, personality traits, and knowledge sources honed during leisure time to the workplace – and thereby to be able to draw on these attitudes and attributes when engaged in inventive activities at work. To take one example, Kotro (2007) describes an engineer who, during leisure time, designed electronic gadgets for his hobby, orienteering. Subsequently hired by a sports firm, the engineer helped his employer to branch into electronic sports equipment, and later into miniaturized computer sports watches.

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[2] We do not claim a direct relationship between hobbies and the fourth factor, intrinsic motivation, since we cannot be certain that an employee who is intrinsically motivated to pursue a given hobby will also be intrinsically motivated to pursue a given task at work. The leisure time hobby could, for example, provide a means for escaping work pressure. However, we control in our analysis for the possible importance of work-time intrinsic motivation.

In the literature, there is some evidence linking leisure time activities to cognitive skills, personality and knowledge. A Whitehall study showed that leisure time activities involving higher levels of cognitive effort or social interaction are associated with individuals with better cognitive abilities (controlling for social and economic status). Individuals who engage in leisure time activities requiring low cognitive effort have lower cognitive ability (Singh-Manoux et al. 2003).

The inventor will arguably also evince the same kinds of personality traits, whether at home or work. Studies utilizing the Five Factor Model of personality (also referred to as "Big Five personality traits": conscientiousness, openness, agreeableness, extraversion and neuroticism.[3]) (McCrae and Costa 1987, 2006, 2012) have found that personality types with a high degree of openness, extraversion, and to some degree, neuroticism, were more creative than other personality types (Batey and Furnham 2010: 396). While the role played by hobbies in this regard is under-researched, Wolfradt and Pretz's (2001) argument that hobbies enhance openness in the individual creative process, is suggestive.

Scholarship on knowledge re/combination shows that creativity should be increased by exposure to a wide variety of ideas and components not previously combined (e.g. Fleming and Sorenson, 2004, Levitt and March 1988, Gray and Meister 2004). A similar theme is struck in the literature on organizational creativity, most particularly the componential model developed by Amabile (e.g. 1983, 1988), which includes a knowledge component (domain-relevant skills), along with creativity-relevant skills and task motivation (later, the work environment was added). Hobbies might be said to reflect the interests of an employee – the more diverse the hobbies pursued, the broader his/her interests. By continually participating in a hobby, employees can also acquire substantial skills and knowledge transferable to a related work area (Postigo 2003, Kotro 2007).

[3] Davis et al. (2013), building on Granovetter's (1973) study of strong and weak ties, showed that there is a positive relationship between the importance of knowledge sources gleaned from people outside the organization and the incidence of "leisure time invention," defined as invention where the main underlying idea occurred while the employee is away from the workplace

An example of acquiring skills while pursuing a hobby which are relevant for work-related tasks concerns the Formula 1 industry. Several automotive engineers, during their youth, constructed race cars for non-commercial events (e.g., soapbox derbies). Adrian Newey (star designer at March F1, Williams F1, McLaren F1, and Red Bull F1) points out that his experience in making model kits of racing machines was key to learning how to improve a car's performance by making technical changes (Grandprix, 2013). In particular, engineers learn how to bring the different parts of the car together, since – during their leisure time – they typically act as "one-man team".

The relationship between leisure time and work time activities

Even though inventors, during their leisure time, are physically removed from the workplace, they often continue to wrestle with work-time problems, consciously or unconsciously. Poincaré graphically describes the creative cognitive process leading to the "sudden illumination" as follows: "Initial intense prior conscious work on the problem is necessary to 'unhook' relevant ideas from fixed positions so that they are free to join during the unconscious process" (quoted in Brown 1989: 5). Olton (1979) refers to this "the incubation effect", a way of thinking that emerges after an interval during which the individual has not consciously worked on a problem.

During their leisure time, employees are exposed a wide spectrum of experiences and knowledge inputs, and may suddenly become aware of unaddressed needs, triggering the proverbial "flash of genius. Such leisure time inspirations, when further nurtured in the workplace may lead to quite valuable inventions: classic examples include the Wright brothers' Flyer 1 and Post-It Notes at 3M[4] (Davis et al. 2013). Since external knowledge sources, when appropriately combined with other internal and external knowledge sources, can enhance innovative performance (e.g. Fleming

[4] For example, the Wright brothers, picnicking in the countryside, suddenly conceived the solution to controlled flight, a problem they had been struggling with, as they gazed at vultures circling in the sky above them. 3M chemist Art Fry, while singing in his church choir, suddenly conceived of a use for a non-sticky adhesive – a new invention made by another 3M chemist that the company, which specialized in sticky adhesives – had put "on the shelf": Fry realized that it could be attached to the back of a small piece of paper to mark his place in the hymnal.

and Sorensen 2004, Laursen and Salter 2006), we believe that mulling over work-related problems during leisure time might lead to potentially valuable new knowledge combinations.

Employees who continue to dwell on work-time inventive problems during leisure time may also be advantaged in that they are less susceptible to problems of path dependency (Coombs and Hull 1998), “competency traps” (Levitt and March 1988), organizational inertia (Hannan and Freeman 1984) and the “availability bias” (Hastie and Dawes 2009)[5]: These have all been negatively related to organizational performance. Engaging in hobbies might enable employees to accumulate different types of skills and capabilities that can potentially be combined with what they are doing at work to produce valuable new knowledge combinations. This leads to our first hypothesis:

> *Hypothesis 1: The extent to which an inventor thinks about a work-time invention during leisure time is positively related to the value of the invention.*

The inventor’s choice of hobbies

Diversity of hobbies

Building on the arguments presented above, one might contend that employees who engage in a wide variety of hobbies should have access to more diverse sources of knowledge than employees who do not. As a result, given the recombinatory and search conditions that are core to technological advances (Fleming and Sorensen, 2000; Fleming, 2001), they should be more likely to put these knowledge sources together in such a way to achieve a valuable result.

Pursuit of multiple hobbies is arguably also indicative of the personality type “open to experience” (for example, amenable to new ideas, experiences, and unconventional perspectives, e.g. McCrae and Costa 1987). A Batey and Furnham (2010) review of studies based on the Five Factor

[5] Path dependency occurs when the firm-specific routines underpinning the innovation process lead to the organization’s failure to adapt to a changing environment. The availability bias refers to the problem that certain knowledge sources may be used simply because they are available.

Personality Model points to a consensus: openness to experience is the strongest indicator of the creativity personality. On this basis, we hypothesize:

Hypothesis 2: The diversity of the hobbies pursued by the inventor is positively related to the value of the invention.

Type of hobbies

The type of hobby practiced by the inventor might also play a role. We divide the types of hobbies into two categories: social vs. individual hobbies, and focused vs. exploratory hobbies. Cooking (Hartel 2007), for example, is a social hobby, because the cook needs not only to think about what recipes might be fun and interesting to create, but also about how well other people will like their creations. Furthermore, cooking is typically pursued together with others. This is different from a hobby like model railway building (King 1996), where what other people think matters less, and which is typically pursued alone. But cooking and model-building also have something in common: to produce a specific end product. This is in contrast to a hobby like traveling (Stebbins 1996) or reading (Schutte and Malouff 2004), where the goal is more diffuse (not just reading the book, for example, but also reveling in colorful prose imagery, gaining new insights into human behavior, being “transported” to far-away, perhaps imaginary worlds, and so forth).

Social vs. individual hobbies. Since social hobbies are typically practiced with others, this will expose the inventor to a wider network of people, which should raise the likelihood that he/she will produce a valuable invention. Theoretical support for this argument is found in the work on strong and weak ties (e.g. Granovetter 1973, Friedkin 1980, and Collins 1974). Weak ties provide access to non-redundant information; strong ties increase the probability that knowledge is shared because of trust, for example – in both cases, the result is higher innovative performance.

A few studies address how leisure time activities might facilitate such ties. For example, Madjar et al. (2002) analyze the linkage between family support and employee work place creativity. Cattani and Ferriani (2008) demonstrate the importance of social network positioning to individual creativity in the Hollywood film industry. This reasoning leads to a third hypothesis:

Hypothesis 3a: Pursuing social hobbies is positively related to the value of the invention.

Focused vs. exploratory hobbies. Whether the employee pursues a hobby with a well-defined, specific goal, or one where the objective is more open-ended and diffuse, should also influence how the employee approaches work-time tasks. The kinds of knowledge obtained while engaging in a focused hobby are arguably deeper and more intense than the knowledge obtained while engaging in a more exploratory hobby. This knowledge might thereby be seen as an indicator of external search depth (defined as the degree to which an entity draws extensively from key external knowledge sources). In the literature (e.g. Katila and Ahuja 2002, Laursen and Salter 2006), external search depth has been positively related to innovation performance. By analogy, the employee inventor's ability to draw deeply on hobby-related knowledge – since it, too, is created externally to the organization – should enhance performance.[6]

Moreover, according to Zhou and George (2001, pp. 515-516), people who score high on the personality trait conscientiousness (for example, purposeful, reliable, self-controlled, scrupulous) show the strongest, most consistent relationship with job performance. We propose that employees with more focused hobbies will also demonstrate greater individual conscientiousness and goal orientation at work than those who pursue more open-ended, exploratory hobbies. Since

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[6] The link between external search depth and innovative performance is true only up to a point: over-search can contribute to lower performance (e.g. Katila and Ahuja 2002, Laursen and Salter 2006). In our view, there will probably not be the same risk of over-search in our context, since the employee inventor will likely have no choice but to combine hobby-related knowledge with the other kinds of knowledge sources typically used at work.

conscientiousness is correlated with performance, we expect that inventors with focused hobbies should be more likely to contribute to organizational creativity:

Hypothesis 3b: Pursuing focused hobbies is positively related to the value of the invention.

METHODOLOGY AND DESCRIPTIVE STATISTICS

Description of the data

To test our hypotheses, we used data drawn from a large-scale survey of inventors matched with information drawn from patent databases of the European Patent Office. All variables were constructed at the level of the invention. The survey data were collected for a project sponsored by the European Commission, InnoS&T ("Innovative S&T indicators combining patent data and surveys: Empirical models and policy analyses"), for 20 European countries, Israel, the U.S., and Japan. The main source used to draw the sample was the EPASYS database as of 04/2008. Information on technological fields was supplemented from the PATSTAT database as of 04/2011. All patent applications to the European Patent Office with priority dates between 2003 and 2005 listing inventors living in these countries at the time of the application were collected. After sampling the patents, the addressee of the survey was chosen at random among the inventors listed on the patent document. Overall, this resulted in 124,134 inventors. 50% of these were from Europe and Israel, 13% from Japan, and 37% from the U.S.

Information about inventor biographies, invention processes, and patent value, for each of these inventions was sought using an online questionnaire offered in 10 languages. 22,557 responses were received, yielding a corrected response rate of 20%. 9,113 observations were removed due to missing values (information regarding the two dependent variables were missing for 8,836 respondents). 9,306 observations were removed since the inventor was not the one on the team who had the idea for the invention. Not restricting the sample to those answers where the surveyed inventors had the idea for the invention would prevent us from analyzing the link between an inventors leisure time activities and the value of inventive outcome. The final sample consists of 4,138 inventions. It does not contain multiple inventions made by the same inventor.

Description of the variables

Dependent variables

Asset value of an invention[7] – Following Harhoff et al. (2003: 1348), we define the asset value of a patent as an approximation of “the prize that the winner of a patent race (with subsequent imperfect patent protection) will perceive”. In other words, the measure reflects the difference between owning a patent and becoming the leader in a technological field and the situation where another organization owns the patent and becomes the leader in a technological field. Thereby it is a proxy for the incentives to engage into a competitive innovation process (Harhoff et al. 2003). The answers were collected providing ten different value categories varying between “less than € 30,000” and “more than € 300 million”. In our regression analysis, to account for the right-skewed distribution of patent value, the logarithm of this variable was used.

Inventive step[8] – Inventive step depicts one of the three requirements of patentability (the other two are novelty and commercial applicability). While the European patents system typically refers to an inventive step, the US patent system uses the term “non-obviousness”. According to Article

[7] The information about the asset value of a patent was received from the questionnaire asking the following question: *This is a <u>hypothetical question</u>. Suppose that on the day in which this patent was applied for, the applicant and you had all the information you have today regarding the value of this and the related patents. In case a potential competitor was interested in buying the whole set of the patents (the patent family including all national patents derived from it), what would have been the minimum price (in EURO) that the applicant should have demanded?*

[8] The information about the inventive step of the invention underlying the patent was also received from the questionnaire: We asked: *We would like to know how you would rate the degree of inventive step (in the US: non-obviousness) of the invention described in the patent application at the time it was filed.*

52(1) in conjunction with Article 56, first sentence, of the European Patent Convention (EPC), inventions involve an inventive step in case they are not obvious to a person skilled in the art. The answers were collected on a 5-point Likert scale (1 = "very low" and 5 = "extremely high").

Explanatory variables

Work-time thoughts impinge on leisure time activities – In our questionnaire, we asked the inventors about the extent to which they thought about the invention underlying the survey outside their working time (e.g., whilst doing sport, driving, in your free time, etc.). The answers were collected on a 6-point Likert scale varying between 1 = "never" and 6 = "very often".

Hobbies – The respondents were further asked about how they spent their leisure time during the time of the invention. Following the Oxford Dictionary definition cited above, nine activities were defined as hobbies: *(1) sport, (2) arts (playing music, singing, painting etc.), (3) attending artistic events (arts and entertainment: listening to music, attending theatre performances, visiting exhibitions, etc.), (4) traveling (for leisure, sports or culture), (5) reading, (6) cooking, (7) model building (i.e. planes, railway, etc.), (8) playing computer games (playing games: using computer for leisure), (9) software design (i.e. software programming or web design).* However we left sport out of our analysis since it cannot unambiguously be categorized in relation to Hypothesis 3a (we did not know whether respondents pursued individual (e.g., running) or team sports (e.g., soccer)).

Respondents were asked how frequently they pursued these activities. The answers were collected on a 6-point Likert scale varying between 0 = "never" and 5 = "very often". To meet our hobby definition, we created eight dummy variables (one for each hobby category) each taking the value of one in case the inventors had answered 4 = "often" or 5 = "very often" and zero otherwise.

Diversity of hobbies – To measure the diversity of hobbies, we calculated the number of hobbies the inventors pursued during the time of the invention.

Types of hobbies: social vs. individual – Social hobbies are defined as hobbies where other people are typically involved in carrying out the hobby, individual hobbies are those where typically only one person is involved. We classify *cooking, arts, attending artistic events, and travelling* as social hobbies and *software design, model building, reading, playing computer games* as individual hobbies.

Types of hobbies: focused vs. exploratory – Focused hobbies involve the purposeful creation of something leading to specific result. Exploratory hobbies involve participating in an already existing activity in a more exploratory manner which does not necessarily lead to a specific result. We classify *cooking, arts, software design, model building* as focused hobbies *and attending artistic events, travelling, reading, playing computer games* as exploratory hobbies.

Figure 1 provides an overview over how we categorized our eight hobbies.[9]

Insert Figure 1 about here

Control variables: Individual characteristics

Intrinsic vs. extrinsic motivation – In our questionnaire we asked the inventors about the motivation for making the underlying invention. Possible motivations were: monetary rewards, career advances, reputation, technological possibilities, intellectual challenge, desire to solve problems. The importance of the motivations were collected on a 5-point Likert scale (1 = not important; 5 = “very important). Based on the cronbach alpha, the first three types of motivation were combined to a variable capturing extrinsic motivation (cronbach alpha = 0.67), the last three

[9] The classification of hobbies in this figure is based on various academic sources either discussing personal attitudes and that are related to hobbies or the personal skills required to practice a hobby successfully: Cooking (Hartel 2007); Active arts (Ivcevic and Mayer 2006-7, Gelade 2002, Juniu,et al. 1996); Software design (Bishop-Clark 1995, Beecham et al. 2008); Model-building (King 1996): Travelling (Stebbins 1996); Arts/entertainment (Stebbins 2007); Reading (Schutte and Malouff 2004, Finn 1999, Boynton 1942); and Computer games (Jeng and Teng 2008, Mehroof and Griffiths 2010).

were combined to a variable capturing intrinsic motivation (cronbach alpha = 0.77). The variables were calculated by summing up the values for each type of motivation and dividing the sum by the number of different motivations. Hence, both variables can vary between 1 and 5.

Age – We added a variable capturing the age of the inventors at the time of the survey.

Level of education – Since inventors are typically characterized by a high level of education (Giuri et al. 2007), we aggregate our education variables to three groups: (1) vocational academy, university studies or lower, (2) doctoral degree, or (3) postdoctoral studies.

Experience – To control for the work experience of the inventors we add another control variable comprising the number of prior European patent applications of the inventors.

Control variables: Group characteristics

Project size – The larger the project the more likely the inventor has to work longer, leaving less time for leisure time activities. Large projects may also be very important for employers. Inventors may therefore not be able to get them out of their heads during leisure time. This would bias our results with respect to work-time thoughts impinging on leisure time activities. We generated an ordinal scaled variable, measured in terms of total labor input, taking values between 1 and 7 according to the intervals: “less than 1 man-month ”, “1-3 man-months”, “4-6 man-months”, “7-12 man-months”, “13-24 man-months”, “25-48 man-months”, “more than 48 man-months”.

Project team size – For the same reasons, we add another control variable to account for this.

Knowledge input – Respondents were asked about the importance of informal meetings or discussions with others (apart from the co-inventors listed on the patent) for making the invention both inside their own organization, and outside it. The former captures internal knowledge inputs, the latter external knowledge inputs. For each category, a dummy variable was created, taking the value of one where the respondent regarded the type of exchange as important, and zero if not.[10] The variable forms a proxy for different problem solving approaches.

Control variables: Organizational characteristics

Technical environment – Inventors were asked whether the organization where they worked at the time of the invention provided a scientifically or technologically stimulating environment. The answers were collected on a 5-point Likert scale (1 = completely disagree; 5 = completely agree). We use this variable as a proxy for the innovation culture of the organization.

Autonomy – The inventors were asked to indicate on a 6-point Likert scale (1 = no autonomy; 6 = very high autonomy) to what extent they were allowed to select their own tasks or projects at the time of the invention. The variable is used as a proxy for the degree of autonomy of the inventor.

Intensity of competition – The inventors were asked whether – at the time of the invention - they were aware of other parties extensively competing for the patent. A dummy variable was created taking the value of one in case the inventors indicated severe competition and zero otherwise. The variable is added to the regression model to control for the environment of the organization.

Firm size – We use an ordinal variable to measure variation in the number of employees. The nine intervals range from “1 to 9 employees” to “more than 5,000 employees”. Firm size provides a proxy for the resources available to an organization.

Other controls

Gender – This dummy variable takes the value of one for male inventors, and zero otherwise.

Hours of work time – To avoid biased results, we add a control variable capturing the workload of the inventors at the time of the invention. We got the information from the questionnaire by asking

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[10] We decided to use two dummy variables instead of ordinal-scaled variables, since the distribution of the variable capturing the importance of exchanges with people outside the organization is extremely skewed to the right and, hence, does not offer enough variation across the different categories to work in the regression analysis (six-point Likert scale ranging from 0 to 5; mean=1.1; median=1).

the inventors about the average number of work-hours per week at the time of the invention. This variable also included overtime. This enables us to disentangle working overtime from thinking about work during leisure time activities, i.e. during an inventor's spare time.

Type of Organization – A dummy variable taking the value of one in case the applicant is a private firm and zero otherwise was added to the regression. The reference group consists of other organizations like universities, public or private research organizations or hospitals.

Status of the patent – Granted patents are more valuable, since they are, e.g., more likely to be commercialized (Gans et al. 2008). Therefore, a dummy variable to indicate the status of the patent application was added as a control. This took the value of one if the patent was granted, and zero if the patent was either withdrawn, rejected by the patent office, or was still pending.

Number of claims – This variable measures the number of claims an applicant requested for his/her patent. Patent claims define the scope of an invention for which patent protection is requested. The latter has been shown to be related to patent value (Gambardella et al. 2008)

Geographic region – To capture unobserved heterogeneity between countries, we add dummy variables denoting the geographical region where the invention was made: northern Europe, central Europe (reference group), southwestern Europe and Israel, the U.S., and Japan. Following existing work (EFI 2013), we use the inventor home countries as proxies for location.

Technological area – Because different technologies may exhibit different patent propensities (Gambardella et al. 2008), we control for this variation in our data by including dummies for the main technological areas (OECD 1994) to which the patents were assigned: electrical engineering, instruments, chemistry (reference group), process engineering, or mechanical engineering.

Table 1 provides an overview over the assignment of the control variables to the different categories provided by Woodman et al. (1993).

Insert Table 1 about here

Descriptive statistics

Table 2 summarizes the descriptive statistics. Asset value varies between 1 (less than 30,000 Euro) and 10 (more than 300 mio Euro). The median amounts to 4 (300,000 – 1 mio Euro). Inventive step varies between 1 (very low) and 5 (extremely high). The median amounts to 3 (medium).

At the time of the invention, the respondents often thought about their work during leisure time (the median of this variable was 4, on a scale from 1 (never) to 6 (very often). They pursued between 0 and 6 different hobbies (0.7 on average). 26% had at least one social hobby, 41% at least one individual hobby. 20% had at least one focused hobby and 35% at least one exploratory hobby. 98% of the inventors in our sample are male. The average age of the respondents was 52 at the time of the survey (varying between 18 and 90 years). 22% have a doctoral degree. The respondents held 37.6 patents on average (range: 1-2000) at the time of the survey. Project size exhibits a median of 4 (4-6 man-months) and varies between zero man-months to over 72 man-months. The project teams varied in size between 1 and 19 inventors, the average was 2. For 29% of the inventions, internal knowledge was important; for 19%, external knowledge was.

50% of the respondents answered that at the time of the invention, they worked in a scientifically or technically stimulating environment. Autonomy was medium (median was 4), varying from 1 to 6. 26% of the respondents reported a high intensity of competition at the time of the invention. Firm size has a median of 8 (1,000-4,999 employees), varying between 1 to over 5,000 employees. 92% of the organizations employing the inventors were private firms. 36% of the patents were granted at the time of the survey (2009). The patent applications contained between 0 and 132 claims; 16 on average[11]. At the time of the invention, 48% of the inventors lived in central Europe, 5% in northern Europe, 9% in southern Europe or Israel, 19% in the US, 19% in Japan. 26% of the inventions were in electrical engineering, 17% in field instruments, 19% in chemistry, 31% in process engineering, and 7% in mechanical engineering.

Figures 2 and 3 show the distributions of the two dependent variables. The correlation matrix is reported in Table 3. Correlations between independent variables are relatively low, indicating that collinearity of covariates should not be a concern.

Insert Table 2, Table 3, Figure 2, and Figure 3 about here

MULTIVARIATE ANALYSIS

To test our hypotheses we use OLS regression models. Due to the right-skewed distribution of asset value, we use a log-log-specification to estimate the determinants of asset value. To explain inventive step, an ordinary OLS regression model is used. Since inventive step only varies between 1 and 5, as a robustness check, we also estimated an ordinary probit model[12]. The results are the same as regards sign and significance. Due to a better interpretability of the coefficients, we provide the results of the OLS regression model for inventive step.

Models 1A to 1G (Table 4) refer to regressions explaining asset value, Models 2A to 2G (Table 5) explain inventive step. Models A contain our control variables. The B Models add the variables capturing the different components of the Woodman et al. (1993) model. The C Models add the variable capturing to which extent the inventors thought about their work during leisure time. Models D to G add the different hobby variables.

[11] Patent applications may have zero claims in case during the examination the patent examiners declare all claims invalid. Zero claims, of course, lead to a refusal of the patent application.

[12] Results of the Ordinary Probit models are available upon request.

We start with presenting the results of the Models 1A to G (asset value). The control variables (Model 1A) exhibit the expected signs. In particular, workload (hours of work-time), number of claims, and inventions in chemicals, are positively related to asset value. U.S.-sourced patents have the highest asset value compared to other countries, possibly because US applicants only file European patents for the most valuable inventions. Surprisingly the dummy capturing private firms is negative; but once we add the other control variables, it becomes insignificant.

Model 1B shows that intrinsic and extrinsic motivation, age, experience, and project size are all positively related to asset value, while internal knowledge shows a negative relationship. Intensity of competition positively affects asset value – which is in line with the definition of asset value, i.e. of winning a patent race. Finally, firm size negatively affects asset value of the patents. The reason may be that large firms often file a patent for every invention, while smaller firms can only afford to file patents for the most promising inventions. None of the other variables are significant.

Model 1C adds the variable controlling for the extent to which the inventors, during their leisure time, think about the underlying invention. This is positively related to asset value; more specifically, if the time inventors think about their work during leisure time increases by 10%, asset value increases by 5%. This confirms our first hypothesis for asset value. Model 1D shows the diversity of hobbies an inventor pursues at the time of the invention. As expected, the more hobbies an inventor has, the higher the asset value of the invention. One more hobby increases asset value by 2%. This confirms our second hypothesis for asset value.

Model 1E shows that inventors who pursue at least one social hobby produce patents with higher asset value; individual hobbies do not have a significant impact. Patents by inventors with a social hobby show an asset value 18% larger than those by inventors who do not pursue this type of hobby. This confirms our third hypothesis (H3a) for asset value. Model 1F contains two dummy variables capturing whether the inventors, at the time of the invention, pursued at least one focused or exploratory hobby. Focused hobbies are positively related to asset value, exploratory hobbies are not significant. Inventors with a focused hobby produce patents 22% more valuable (asset value) than inventors without such a hobby. This confirms Hypothesis 3b for asset value.

Table 5 provides the results for inventive step. The control variables (Model 2A) show the same basic effects as were found for asset value. There were no divergent results with respect to intrinsic vs. extrinsic motivation, age, experience, project size, knowledge input, or inventor team size (Model 2B). We do, however, find a positive effect of post-doctoral studies on inventive step (compared to the control group: educational degree lower than PhD). Autonomy has a positive and significant impact on inventive step, whereas it had no significant effect on asset value.

We also find that thinking about work-related problems during leisure time increases inventive step (Model 2C). If the time inventors think about this during leisure time increases by one unit, inventive step increases by 0.08 units. This confirms our first hypothesis for inventive step. A larger diversity of hobbies also increases inventive step (Model 2D). One more hobby increases inventive step by 0.05 units. This confirms our second hypothesis for inventive step.

Model 2E reveals that both, social and individual hobbies positively affect inventive step. A Wald test shows that we cannot reject the null hypothesis that the two coefficients have the same size ($F = 0.11$; $p = 0.746$). Patents by inventors who have a social hobby have an inventive step 0.06 units larger than patents by inventors who do not. Focused hobbies increase inventive step by 0.07 units. This result does not provide support of our third hypothesis (H3a). Exploratory hobbies positively affect inventive step, focused hobbies do not (Model 2F). Exploratory hobbies increase the inventive step by 0.07 units. While these results do not support our last hypothesis (H3b), this finding is very interesting. It suggests that asset value may be related to goal-oriented (focused) hobbies, while inventive step is more closely related to exploratory hobbies.

As an extension to the analysis, we tested combinations of hobbies (i.e. social/focused hobbies, individual/focused hobbies, social/exploratory hobbies, and individual/exploratory). The results are also displayed in Tables 4 and 5 (G Models). Models 1G and 2G reveal that hobbies that are both social and focused (e.g. cooking and active arts) positively affect both asset value (increase by 23%) and inventive step (increase by 0.07 units). Individual and exploratory hobbies (e.g. reading and playing computer games) are not significant for asset value, but positively affect inventive step (increase by 0.07 units). The combinations social/exploratory and individual/focus are not significant. These results confirm that inventors who have hobbies that are both social and focused tend to produce the most valuable inventions, which is in line with the logic of our hypotheses 3a and 3b. But there seem to be two “poles” here, given that the above logic cannot explain why the combination individual/exploratory hobbies also lead to more radical inventions.

Insert Table 4 and Table 5 about here

DISCUSSION AND CONCLUSION

Contributions and Implications

As Brusconi et al. (2001) noted, the modern firm “knows more than it makes.” This paper explores the conditions under which employee inventors produce more valuable inventions in an organizational context. The nature of this link is both complex and elusive, since much of what the employee brings to work is unobservable and subject to team and organizational dynamics. Our study bears a resemblance to previous work on team performance and demographic make-up (Reagans and Zuckerman 2001, Reagans et al. 2004), on the impact of domestic leisure time on workplace performance (Madjar et al. 2002), and on the impact of hobbies on individual creativity (e.g. Csikszentmihalyi & LeFevre 1989, Root-Bernstein, Bernstein, Garnier 1995, Kotro 2007).

But to our knowledge, our paper is the first to empirically investigate the relationship between employee inventor leisure time activities and the value of their workplace output.

Our findings show that continuing to think about workplace research during leisure time, pursuing a wide range of hobbies, engaging in more socially oriented hobbies and more focused hobbies, are all positively related to invention value. As regards asset value, this indicates, for example, that inventors benefit from access to external information, which they can get from their ties during pursuing social hobbies. But increasing inventive step requires more than information; it probably requires out of the box thinking. Inventive step is a proxy for innovation radicalness. According to Miron-Spektor et al. (2011), to create radical innovations, inventor teams should consist of creative and conformist members. The latter are rather detrimental to radical innovation, but contribute in other ways: by reducing task conflicts and enhancing team performance. Thus both are needed: the conformists to focus on details and stick to standards, the creative people to take risks and improvise. This is in line with our results, suggesting that focused hobbies are positively related to the asset value of an invention and exploratory hobbies are positively related to inventive step (i.e. the radicalness) of an invention.

We contribute to theory development, first, by showing how the Woodman et al. (1993) model can enable us to disentangle the effects of individual employee characteristics on organizational creativity more generally. Second, we add to both the organizational creativity literature and the search and knowledge re/combination literature by combining the two approaches in the context of the Woodman et al. framework. By conceptualizing hobby-related knowledge as a source of external knowledge, we demonstrate how the search for relevant knowledge sources outside the organization could be expanded to include a further potentially important knowledge source: that garnered while the employee is engaging in leisure time activities.

We also add to the literature on the determinants of invention value. Gambardella et al. (2006) find that the characteristics of the individual inventor provide better predictors of patent value than the characteristics of the organization itself. Research including individual characteristics has so far mainly considered education or work-related characteristics like the level or field of education or patent experience (Hoisl 2007). We enlarge the set of individual inventor-related predictors of patent value by adding a completely new dimension, i.e. a leisure-time related factor.

Furthermore, hobbies have been related to task motivation (Postigo 2003). Even though research on the importance of motivation for inventive output exists (e.g., Sauerman and Cohen 2010), motivations like advancement or intellectual challenge are still closely related to the job of the inventors and are typically endogenous. In particular, these types of motivation may be influenced by employer incentive systems to reach a certain goal, i.e. to produce a valuable invention. But hobbies are to a large extent independent of the inventor's work environment; employers do not force their employees into particular hobbies. Hence, hobbies may be used as an exogenous measure for an inventor's task motivation. The latter also provides a methodological contribution.

Our analysis carries several implications for management. Our findings show that leisure time activities matter when it comes to R&D employee performance on the job. This implies that supporting employee leisure time activities both on and off the job may yield rewards. For instance, allowing employees to pursue social hobbies during their lunch break could provide the inventor team with potentially valuable additional knowledge inputs. Hobbies could supplant or complement firm policies such as Google’s 80/20 policy, which allows engineers to spend 20 percent of their work time in the free pursuit of their interests.[13] Simple policies such as allowing

[13] An interesting aspect of our study deals with the degree of sociability involved in hobbies. Engineers using their free time privately (as in the Google 80/20 program) will have a tendency to tackle their work time projects (where there is pressure to perform) to the detriment of their free time. On the other hand, allowing employees from different departments to play chess or bridge in their lunch breaks allows for freer exchange of ideas and a broader set of social networks within the firm, allowing for higher organizational productivity.

engineers to take their tools home with them, or encouraging hobby groups among R&D employees, could enable a better functioning open (minded) innovation environment at the firm. Furthermore, hobbies may well depict an observable determinant of productivity-enhancing hires and could therefore be used by the human resources department for recruiting purposes.

Limitations and Future Research

This paper is based exclusively on inventions for which a European patent was filed. We cannot assume that our results apply to the full population of inventions. Not all inventions are patented (at the European Patent Office or at all) or patentable (Cohen et al. 2000). Second, we surveyed only one inventor per invention; in cases where the invention was made by an inventor team, other team members also contributed. However, the fact that we limited our analysis to those inventions where the surveyed inventor had the idea for solving the respective problem makes us confident that we do not only observe artefacts.

Furthermore, even though we do not claim causal relationships in our paper, endogeneity should be discussed. Whereas we are confident that personal traits are inherent (Lykken and Tellegen 1996) and hobbies are not forced on inventors by employers, the variable capturing the extent to which the inventors, at the time of the invention, thought about work related issues might not be fully exogenous. In particular, the larger a project is and the more important a project is to the employer, the higher the probability that the inventors cannot get their work out of their heads during their leisure time. To reduce the probability of an endogeneity problem, we controlled for the size of the project and the size of the project team. Furthermore, we added a control variable capturing the number of working hours of the inventors at the time of the invention. The fact that this variables explicitly included overtime helps us to disentangle pure leisure time from working at home during the weekend. Finally, the question regarding the extent to which inventors think about their work during their leisure time explicitly referred to time of pursuing hobbies.

Our results also open up important questions that can be addressed in future research: First, in this paper, we combined the Woodman et al. (1993) framework with the search and knowledge re/combination literature (e.g. Fleming and Sorensen 2001) to understand the impact of employee leisure time activities on workplace creativity. But this combination could also be used to investigate other aspects of how knowledge workers create valuable inventions. Further studies could analyze the potential role of hobbies as part of the firm's larger open innovation approach.

Moreover, future research could expand on themes that our data cannot illuminate. For example, our data allow us to control for the extent to which the organization provided a scientifically or technically stimulating environment or the degree of autonomy of the inventors. However, we do not observe the mechanism within the organization (black box) between inputs and outputs, which is part of the "transformation" processes (creative behavior, creative situation) described by Woodman et al. (1993) (Figure 2, p. 309).

One of our most intriguing findings, as discussed above, is that focused hobbies are positively related to asset value but not inventive step, and exploratory hobbies are positively related to inventive step but not asset value. We speculated above that this might be explained by differences between the two groups of hobbyists as regards how they approach inventive problem-solving. Further research may take a closer look at the differences between various value measures to get an even better understanding of the leisure time – creativity relationship.

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Figure 1: Matrix (types of hobbies)

Vertical axis measures whether hobbies are primarily social or individual
Horizontal axis measures whether hobbies are primarily focused or exploratory

	FOCUSED Involve the purposeful creation of something, aiming for a specific end result	**EXPLORATORY** Involve participating in an activity in a more exploratory, open-ended manner
MORE SOCIAL Where other people are typically more involved in carrying out the hobby	*Hobbies:* - Cooking - Arts: playing music, singing, painting, etc.	*Hobbies:* - Attending artistic events (Arts and entertainment: listening to music, attending theatre performances, visiting exhibitions, etc.) - Traveling for leisure, sports or culture
MORE INDIVIDUAL Where other people are typically less involved in carrying out the hobby	*Hobbies:* - SW design - Model building (i.e. planes, railway, etc.)	*Hobbies:* - Reading - Playing games, using computer for leisure

Figure 2: Distribution asset value (N = 4,138)

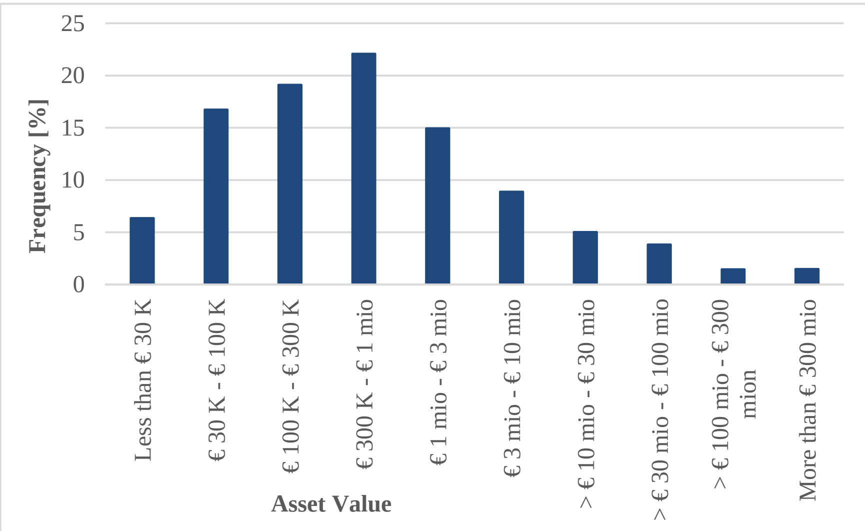

Figure 3: Distribution inventive step (N = 4,138)

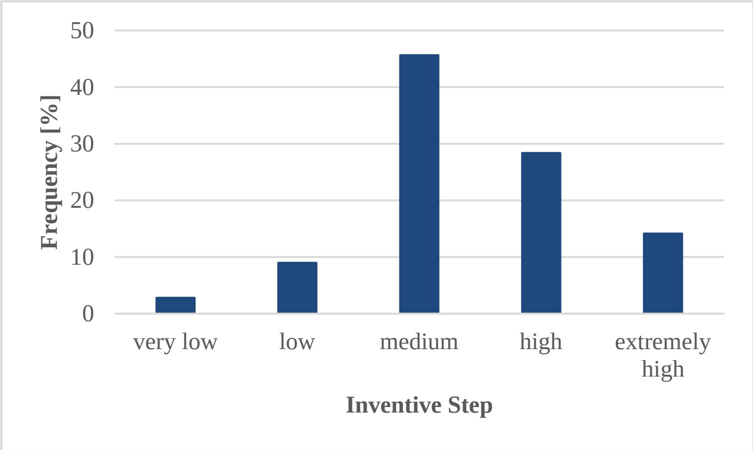

TABLE 1: Definition of the variables (based on Fig. 2 in Woodman et al., 1993, p. 309)
(all these variables were used in the regressions sent by Karin on 24.7, or suggested by her. Project size and knowledge sourcing have been added, firm size kept as a control.)

Input: Woodman et al.	Definition (fx from W paper)	Our questions
1) Individual characteristics • Cognitive abilities/style • Personality • Intrinsic motivation • Knowledge	• a) Fluency, flexibility, originality, divergent and convergent thinking • b) Broad interests, attraction to complexity, high energy, independence, curiosity • c) Where creativity is motivated inherent interest as opposed to monetary/career rewards • d) Technical skills, talent, previous experience and learning	• Explanatory variables - D6: LT thoughts - G11 – Hobbies • Controls (intrinsic motivation) - D3: Intrinsic/extrinsic motivation Composite - G2: Age • Controls (knowledge) - A1: level of education, - experience (no of patents)
2) Group characteristics • Norms • Cohesiveness • Size • Diversity • Roles • Task • Problem-solving approaches	• Generally: Probability of creative outcomes may be highest when leadership is democratic and collaborative, structure is organic rather than mechanistic, and groups are composed of individuals drawn from diverse fields or functional backgrounds. • Problem-solving fx via brainstorming	• Controls - C32 – project size Inventor team size - C11 – source knowledge from other organizations
Organizational characteristics • Culture • Resources • Rewards • Strategy • Structure • Technology	• Creativity training, support for divergent thinking Autonomy, flexibility, degree of supervision • Level of rewards and achievement motivation Communication, information exchange	• Controls - D9 – organization had a scientifically or technically stimulating environment - D7 – inventor is allowed to select his own tasks - C19 – during the invention process inventors were aware of several competitors - B3 - firm size

Other controls: Gender; D4 – WT; patent variables (granted, claims); geographic region; technology area

Table 2: Descriptive statistics (N = 4,138)

Variable	Mean	Std. Dev.	Min	Max
Asset value (*)	4		1	10
Inventive step (*)	3		1	5
Work-time thoughts during leisure time (*)	4		1	6
Diversity of hobbies	0.69	0.97	0	6
Social hobbies (dummy)	0.26		0	1
Individual hobbies (dummy)	0.41		0	1
Focused hobbies (dummy)	0.20		0	1
Exploratory hobbies (dummy)	0.35		0	1
Focused & social hobbies (dummy)	0.15		0	1
Focused & individual hobbies (dummy)	0.06		0	1
Exploratory & social hobbies (dummy)	0.16		0	1
Exploratory & individual hobbies (dummy)	0.26		0	1
Intrinsic motivation	2.34	1.03	1	5
Extrinsic motivation	4.04	0.92	1	5
Age	52.34	10.20	18	90
Lower degrees (dummy)	0.76		0	1
PhD degree (dummy)	0.22		0	1
Post doctoral studies (dummy)	0.03		0	1
Experience	37.64	80.77	1	2000
Project size (*)	4		1	9
Inventor team size	1.80	1.31	1	19
Konwledge input (internal) (dummy)	0.39		0	1
Konwledge input (external) (dummy)	0.19		0	1
Technical environment (dummy)	0.50		0	1
Autonomy (*)	4		1	6
Intensity of competition (dummy)	0.26		0	1
Firm size (*)	8		1	9
Gender (men = 1)	0.98		0	1
Hours of work time (log)	44.30	15.44	0	84
Type of organization (private firm =1)	0.92		0	1
Status of the patent (granted = 1)	0.36		0	1
Number of claims (log)	16.11	10.90	0	132
Central Europe (dummy)	0.48		0	1
Northern Europe (dummy)	0.05		0	1
Southwestern Europe (dummy)	0.09		0	1
U.S. (dummy)	0.19		0	1
Japan (dummy)	0.19		0	1
Elecrical Engineering (dummy)	0.26		0	1
Instruments (dummy)	0.17		0	1
Chemistry (dummy)	0.19		0	1
Process Engineering (dummy)	0.31		0	1
Mechanical Engineering (dummy)	0.07		0	1

* Median

Table 3: Correlation matrix (N = 4,138)

	Variables	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1	Asset value	1																						
2	Inv. Step	0.29	1																					
3	WT thoughts LT	0.17	0.21	1																				
4	Div. of hobbies	0.07	0.09	0.04	1																			
5	Social hobbies	0.06	0.06	0.03	0.72	1																		
6	Individual hobbies	0.0013	0.06	0.07	0.58	0.22	1																	
7	Focused hobbies	0.06	0.05	0.06	0.65	0.62	0.30	1																
8	Exploratory hobbies	0.05	0.08	0.02	0.77	0.50	0.60	0.23	1															
9	F&S hobbies	0.06	0.05	0.04	0.57	0.71	0.18	0.85	0.19	1														
10	F&Il hobbies	0.02	0.03	0.07	0.41	0.08	0.30	0.51	0.15	0.06	1													
11	E&S hobbies	0.05	0.05	0.02	0.60	0.73	0.15	0.17	0.59	0.17	0.06	1												
12	E&I hobbies	0.04	0.07	0.01	0.67	0.19	0.72	0.18	0.81	0.13	0.16	0.16	1											
13	Intrinsic mot.	0.09	0.09	0.09	0.11	0.10	0.05	0.07	0.08	0.07	0.03	0.08	0.06	1										
14	Extrinsic mot.	0.14	0.18	0.25	0.11	0.07	0.14	0.10	0.08	0.08	0.06	0.03	0.09	0.19	1									
15	Age	0.14	0.14	0.17	-0.02	-0.04	0.02	-0.04	0.01	-0.05	0.00	-0.02	0.03	-0.11	0.09	1								
16	Lower degrees	-0.09	-0.12	-0.04	-0.05	-0.04	-0.04	-0.03	-0.06	-0.04	0.03	-0.02	-0.06	-0.04	-0.04	-0.12	1							
17	PhD degree	0.06	0.08	0.01	0.02	0.02	0.03	0.01	0.04	0.03	-0.04	0.00	0.05	0.03	0.02	0.08	-0.92	1						
18	Post doc studies	0.08	0.11	0.07	0.07	0.05	0.02	0.05	0.06	0.04	0.02	0.05	0.04	0.04	0.04	0.10	-0.31	-0.09	1					
19	Experience	0.09	0.06	-0.01	-0.002	0.001	-0.01	-0.02	0.01	-0.01	-0.006	0.01	0.002	0.04	0.02	0.07	-0.05	0.06	-0.01	1				
20	Project size	0.25	0.22	0.16	0.05	0.03	-0.03	0.01	0.05	0.01	-0.01	0.03	0.05	0.07	0.13	0.08	-0.13	0.09	0.09	0.02	1			
21	Inv. team size	0.07	0.05	-0.04	0.04	0.02	0.01	0.01	0.04	0.02	-0.02	0.02	0.05	0.01	0.02	-0.05	-0.11	0.09	0.05	0.05	0.17	1		
22	Konwledge (internal)	-0.01	-0.03	0.01	0.06	0.05	0.05	0.01	0.07	0.01	0.006	0.07	0.04	0.06	0.04	-0.09	-0.05	0.06	-0.02	-0.02	0.10	0.09	1	
23	Konwledge (external)	0.05	0.04	0.10	0.06	0.04	0.05	0.03	0.06	0.01	0.02	0.05	0.05	0.06	0.07	0.03	-0.04	0.03	0.03	-0.02	0.14	0.03	0.30	1
24	Techn.al environm.	0.05	0.06	0.02	0.04	0.06	0.02	0.01	0.05	0.02	0.00	0.07	0.02	0.05	0.08	0.06	-0.10	0.08	0.07	0.01	0.07	0.03	0.12	0.04
25	Autonomy	0.14	0.19	0.22	0.05	0.04	0.03	0.04	0.05	0.03	0.02	0.04	0.04	0.03	0.13	0.24	-0.10	0.07	0.09	0.03	0.16	-0.02	-0.01	0.08
26	Competition	0.02	0.01	-0.12	0.03	0.02	-0.03	-0.002	0.03	0.00	-0.004	0.03	0.02	0.07	-0.04	-0.11	0.03	-0.03	0.005	0.14	0.13	0.08	-0.001	0.02
27	Firm size	-0.10	-0.14	-0.22	-0.01	0.02	0.0010	0.001	-0.02	0.01	-0.01	0.01	-0.03	0.03	-0.07	-0.24	0.002	0.01	-0.03	0.09	-0.10	0.14	0.08	-0.09
28	Gender	0.03	0.01	0.01	-0.04	-0.06	-0.05	-0.06	-0.05	-0.08	0.04	0.01	-0.07	0.01	-0.04	0.05	0.07	-0.06	-0.01	0.02	-0.06	0.0014	-0.04	-0.03
29	Hours of work	0.11	0.07	0.05	-0.02	-0.03	-0.02	-0.03	-0.01	-0.03	-0.01	-0.02	0.01	0.01	0.03	0.03	-0.05	0.04	0.01	0.06	0.11	0.03	0.03	0.03
30	Organization	-0.06	-0.14	-0.09	-0.005	-0.01	0.01	-0.01	-0.01	-0.02	0.01	0.01	-0.01	-0.02	-0.04	-0.08	0.32	-0.21	-0.29	0.04	-0.14	-0.04	0.04	-0.04
31	Status patent	-0.07	-0.04	0.03	-0.03	-0.02	0.002	-0.01	-0.04	-0.02	-0.001	-0.01	-0.05	-0.05	-0.03	-0.01	0.06	-0.04	-0.03	-0.02	-0.08	-0.05	0.01	0.01
32	Number claims	0.15	0.08	0.07	0.02	0.02	0.01	0.01	0.02	0.02	0.00	0.01	0.02	0.06	0.05	0.07	-0.13	0.11	0.07	0.03	0.11	0.11	0.02	0.02
33	Central Europe	-0.16	-0.10	0.17	-0.06	-0.04	0.02	-0.01	-0.08	-0.02	0.02	-0.04	-0.06	-0.11	-0.06	-0.002	-0.02	0.03	-0.02	-0.09	-0.18	-0.10	0.02	0.03
34	Northern Europe	0.05	-0.04	0.00	0.01	0.04	0.003	0.04	-0.01	0.06	-0.01	-0.01	-0.01	0.003	0.03	0.001	0.02	-0.02	0.01	-0.04	-0.01	-0.04	0.02	0.01
35	Southw. Europe	0.06	0.05	0.06	0.06	0.02	0.02	0.01	0.06	-0.02	0.05	0.05	0.05	-0.002	0.04	0.04	0.08	-0.09	0.02	-0.08	0.08	-0.05	-0.05	0.04
36	U.S.	0.20	0.12	0.02	0.04	0.04	0.01	0.02	0.05	0.03	-0.02	0.04	0.03	0.12	0.10	0.20	-0.14	0.11	0.09	0.02	0.09	0.10	0.05	-0.01
37	Japan	-0.07	-0.003	-0.28	-0.02	-0.03	-0.06	-0.04	0.01	-0.02	-0.03	-0.02	0.02	0.02	-0.08	-0.23	0.10	-0.07	-0.08	0.18	0.08	0.10	-0.05	-0.06
38	Elecrical Eng.	-0.04	-0.02	-0.05	0.01	0.03	-0.02	0.01	-0.005	0.01	0.01	0.04	-0.02	0.07	-0.02	-0.10	0.04	-0.03	-0.03	0.04	-0.08	-0.05	0.02	-0.04
39	Instruments	0.02	0.04	0.01	-0.01	0.002	-0.01	-0.005	0.01	0.003	-0.01	-0.02	0.007	0.03	0.006	0.02	-0.06	0.05	0.03	-0.005	-0.02	0.02	0.01	0.01
40	Chemistry	0.12	0.09	-0.03	0.07	0.06	0.04	0.04	0.08	0.07	-0.04	0.02	0.09	0.002	0.03	0.05	-0.30	0.26	0.12	-0.01	0.21	0.15	0.02	0.02
41	Process Eng.	-0.08	-0.08	0.05	-0.06	-0.07	-0.02	-0.04	-0.07	-0.07	0.03	-0.03	-0.06	-0.08	-0.01	0.03	0.21	-0.18	-0.07	-0.01	-0.09	-0.08	-0.04	-0.01
42	Mechanical Eng.	-0.02	-0.02	0.03	-0.01	-0.02	0.00	-0.01	0.00	-0.01	0.0006	-0.03	-0.001	-0.02	-0.002	-0.005	0.11	-0.10	-0.04	-0.03	-0.02	-0.03	-0.02	0.03

	Variables	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42
24	Techn.al environm.	1																		
25	Autonomy	0.15	1																	
26	Competition	-0.06	-0.02	1																
27	Firm size	0.01	-0.27	0.12	1															
28	Gender	-0.04	0.03	0.01	-0.03	1														
29	Hours of work	0.04	0.06	0.05	-0.03	0.01	1													
30	Organization	-0.05	-0.12	0.01	0.05	0.05	0.00	1												
31	Statuse patent	-0.01	-0.06	-0.06	0.02	0.01	-0.06	0.03	1											
32	Number claims	0.06	0.10	-0.05	-0.08	0.00	0.06	-0.08	-0.11	1										
33	Central Europe	-0.03	-0.06	-0.29	0.02	-0.01	-0.15	-0.01	0.19	-0.08	1									
34	Northern Europe	0.05	0.02	-0.06	-0.05	-0.02	-0.05	0.001	-0.001	0.001	-0.22	1								
35	Southw. Europe	0.00	0.11	-0.02	-0.22	0.01	-0.02	-0.04	0.02	-0.02	-0.31	-0.07	1							
36	U.S.	0.12	0.09	-0.11	-0.04	-0.01	0.15	-0.0004	-0.17	0.27	-0.46	-0.11	-0.15	1						
37	Japan	-0.12	-0.11	0.53	0.22	0.02	0.08	0.05	-0.09	-0.16	-0.46	-0.11	-0.15	-0.23	1					
38	Elecrical Eng.	0.03	-0.07	0.04	0.10	0.04	0.02	0.05	-0.08	0.04	-0.05	0.02	-0.07	0.04	0.06	1				
39	Instruments	0.02	0.02	0.03	-0.05	0.00	0.03	-0.09	-0.06	0.05	-0.04	-0.002	-0.05	0.07	0.02	-0.27	1			
40	Chemistry	0.06	0.07	0.04	0.02	-0.13	0.02	-0.14	-0.04	0.09	-0.06	-0.006	-0.01	0.06	0.02	-0.29	-0.22	1		
41	Process Eng.	-0.06	-0.05	-0.07	-0.01	0.06	-0.04	0.11	0.15	-0.13	0.12	-0.01	0.05	-0.11	-0.07	-0.40	-0.30	-0.33	1	
42	Mechanical Eng.	-0.06	0.07	-0.05	-0.11	0.01	-0.03	0.05	0.03	-0.05	0.02	0.01	0.11	-0.06	-0.05	-0.16	-0.12	-0.13	-0.18	1

Note: Pearson correlation coefficients (for two continuous variables), point biserial coefficients (for one continuous variable and one dummy variable) and phi coefficients (for two dummy variables)

Table 4: OLS Regression – Determinants of asset value

	Model (1A)	Model (1B)	Model (1C)	Model (1D)	Model (1E)	Model (1F)	Model (1G)
VARIABLES	log(asset value)	log(asset value)	log(asset value)	log(asset value)	log(asset value)	log(asset value)	log(asset value)
Work-time thoughts during leisure time (log)			0.455***				
			[0.079]				
Diversity of hobbies (log)				0.153**			
				[0.070]			
Social hobbies (dummy)					0.179**		
					[0.078]		
Individual hobbies (dummy)					-0.073		
					[0.068]		
Focused hobbies (dummy)						0.224***	
						[0.087]	
Exploratory hobbies (dummy)						0.041	
						[0.071]	
Focused & social hobbies (dummy)							0.232**
							[0.096]
Focused & individual hobbies (dummy)							0.167
							[0.147]
Exploratory & social hobbies (dummy)							0.117
							[0.093]
Exploratory & individual hobbies (dummy)							-0.016
							[0.078]
Intrinsic motivation (log)		0.205***	0.177**	0.195***	0.198***	0.197***	0.194***
		[0.075]	[0.072]	[0.075]	[0.075]	[0.075]	[0.075]
Extrinsic motivation (log)		0.347***	0.230**	0.327***	0.351***	0.321***	0.325***
		[0.120]	[0.116]	[0.120]	[0.120]	[0.120]	[0.120]
Age (log)		0.588***	0.533***	0.601***	0.617***	0.614***	0.628***
		[0.188]	[0.182]	[0.187]	[0.188]	[0.187]	[0.188]
Level of education (reference group: lower degrees)							
PhD degree (dummy)		-0.001	0.013	-0.004	0.001	-0.002	0.001
		[0.089]	[0.086]	[0.089]	[0.089]	[0.089]	[0.089]
Post doctoral studies (dummy)		0.337	0.334	0.313	0.327	0.312	0.308
		[0.226]	[0.204]	[0.227]	[0.226]	[0.227]	[0.227]
Experience (log)		0.142***	0.137***	0.141***	0.139***	0.141***	0.139***
		[0.033]	[0.031]	[0.033]	[0.033]	[0.033]	[0.033]
Project size (log)		0.653***	0.597***	0.655***	0.649***	0.657***	0.656***
		[0.070]	[0.067]	[0.070]	[0.070]	[0.070]	[0.070]
Inventor team size (log)		0.078	0.084	0.075	0.079	0.078	0.078
		[0.097]	[0.096]	[0.097]	[0.097]	[0.097]	[0.098]
Konwledge input (internal) (dummy)		-0.157**	-0.153**	-0.163**	-0.158**	-0.158**	-0.160**
		[0.070]	[0.071]	[0.070]	[0.070]	[0.070]	[0.070]
Konwledge input (external) (dummy)		0.074	0.058	0.068	0.073	0.068	0.067
		[0.087]	[0.087]	[0.087]	[0.087]	[0.087]	[0.087]
Technical environment (dummy)		-0.036	-0.021	-0.039	-0.041	-0.035	-0.039
		[0.066]	[0.066]	[0.066]	[0.066]	[0.066]	[0.066]
Autonomy (log)		0.066	0.024	0.063	0.064	0.061	0.060
		[0.075]	[0.072]	[0.075]	[0.075]	[0.075]	[0.075]
Intensity of competition (dummy)		0.164*	0.159*	0.161*	0.158*	0.160*	0.157*
		[0.090]	[0.088]	[0.090]	[0.090]	[0.090]	[0.090]
Firm size (log)		-0.203***	-0.173***	-0.202***	-0.203***	-0.203***	-0.204***
		[0.057]	[0.054]	[0.057]	[0.057]	[0.057]	[0.057]
Gender (men = 1)	0.702***	0.635***	0.629***	0.659***	0.649***	0.671***	0.658***
	[0.225]	[0.219]	[0.227]	[0.219]	[0.220]	[0.220]	[0.220]
Hours of work time (log)	0.189***	0.134***	0.124**	0.137***	0.138***	0.137***	0.139***
	[0.053]	[0.052]	[0.053]	[0.052]	[0.051]	[0.051]	[0.051]
Type of organization (private firm =1)	-0.291**	-0.082	-0.050	-0.090	-0.080	-0.087	-0.087
	[0.140]	[0.145]	[0.132]	[0.145]	[0.145]	[0.145]	[0.145]
Status of the patent (granted = 1)	-0.093	-0.060	-0.066	-0.057	-0.059	-0.058	-0.060
	[0.069]	[0.067]	[0.069]	[0.067]	[0.067]	[0.067]	[0.067]
Number of claims (log)	0.384***	0.303***	0.300***	0.304***	0.304***	0.304***	0.304***
	[0.060]	[0.059]	[0.060]	[0.058]	[0.059]	[0.058]	[0.058]
Geographic region (reference group: central Europe)							
Northern Europe (dummy)	0.797***	0.688***	0.740***	0.683***	0.674***	0.675***	0.672***
	[0.158]	[0.158]	[0.151]	[0.158]	[0.158]	[0.158]	[0.158]
Southwestern Europe (dummy)	0.749***	0.495***	0.539***	0.478***	0.489***	0.488***	0.485***
	[0.120]	[0.119]	[0.118]	[0.120]	[0.120]	[0.120]	[0.120]
U.S. (dummy)	1.020***	0.754***	0.814***	0.750***	0.748***	0.749***	0.749***
	[0.102]	[0.103]	[0.095]	[0.103]	[0.103]	[0.103]	[0.103]
Japan (dummy)	0.060	-0.186*	-0.028	-0.185*	-0.180	-0.178	-0.170
	[0.088]	[0.112]	[0.114]	[0.112]	[0.112]	[0.112]	[0.112]
Technological area (reference group: chemistry)							
Elecrical Engineering (dummy)	-0.629***	-0.394***	-0.419***	-0.386***	-0.394***	-0.386***	-0.390***
	[0.104]	[0.106]	[0.101]	[0.106]	[0.106]	[0.106]	[0.106]
Instruments (dummy)	-0.438***	-0.289***	-0.317***	-0.279**	-0.284**	-0.278**	-0.278**
	[0.113]	[0.111]	[0.109]	[0.111]	[0.111]	[0.111]	[0.112]
Process Engineering (dummy)	-0.617***	-0.437***	-0.469***	-0.422***	-0.426***	-0.422***	-0.422***
	[0.100]	[0.101]	[0.101]	[0.102]	[0.102]	[0.101]	[0.102]
Mechanical Engineering (dummy)	-0.546***	-0.411***	-0.439***	-0.398***	-0.400***	-0.397***	-0.393***
	[0.148]	[0.149]	[0.152]	[0.149]	[0.149]	[0.149]	[0.149]
Constant	4.610***	0.889	0.715	0.792	0.744	0.727	0.687
	[0.352]	[0.820]	[0.821]	[0.821]	[0.824]	[0.821]	[0.824]
Observations	4,138	4,138	4,138	4,138	4,138	4,138	4,138
R-squared	0.085	0.135	0.141	0.136	0.136	0.136	0.137
F test	28.02	23.16	24.17	22.45	21.78	21.73	20.41

Robust standard errors in brackets / *** p<0.01, ** p<0.05, * p<0.1

Table 5: OLS Regression – Determinants of inventive step

VARIABLES	Model (2A) inventive step	Model (2B) inventive step	Model (2C) inventive step	Model (2D) inventive step	Model (2E) inventive step	Model (2F) inventive step	Model (2G) inventive step
Work-time thoughts during leisure time			0.082***				
			[0.010]				
Diversity of hobbies				0.052***			
				[0.015]			
Social hobbies (dummy)					0.057*		
					[0.032]		
Individual hobbies (dummy)					0.072**		
					[0.029]		
Focused hobbies (dummy)						0.052	
						[0.036]	
Exploratory hobbies (dummy)						0.074**	
						[0.030]	
Focused & social hobbies (dummy)							0.070*
							[0.040]
Focused & individual hobbies (dummy)							0.044
							[0.060]
Exploratory & social hobbies (dummy)							0.058
							[0.038]
Exploratory & individual hobbies (dummy)							0.066**
							[0.032]
Intrinsic motivation		0.045***	0.036***	0.041***	0.042***	0.042***	0.041***
		[0.014]	[0.014]	[0.014]	[0.014]	[0.014]	[0.014]
Extrinsic motivation		0.125***	0.099***	0.120***	0.118***	0.121***	0.120***
		[0.016]	[0.016]	[0.016]	[0.016]	[0.016]	[0.016]
Age		0.005***	0.005***	0.006***	0.006***	0.006***	0.006***
		[0.002]	[0.001]	[0.002]	[0.002]	[0.002]	[0.002]
Level of education (reference group: lower degrees)							
PhD degree (dummy)		0.053	0.061*	0.051	0.050	0.050	0.050
		[0.037]	[0.036]	[0.037]	[0.037]	[0.037]	[0.037]
Post doctoral studies (dummy)		0.279***	0.272***	0.261***	0.269***	0.264***	0.262***
		[0.089]	[0.086]	[0.089]	[0.088]	[0.089]	[0.089]
Experience		0.001**	0.000***	0.001**	0.001**	0.001**	0.001**
		[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
Project size		0.068***	0.058***	0.068***	0.069***	0.068***	0.068***
		[0.008]	[0.008]	[0.008]	[0.008]	[0.008]	[0.008]
Inventor team size		0.015	0.015	0.014	0.014	0.014	0.014
		[0.010]	[0.011]	[0.010]	[0.010]	[0.010]	[0.010]
Konwledge input (internal) (dummy)		-0.087***	-0.084***	-0.091***	-0.091***	-0.091***	-0.090***
		[0.030]	[0.030]	[0.030]	[0.030]	[0.030]	[0.030]
Konwledge input (external) (dummy)		0.017	0.006	0.013	0.012	0.013	0.012
		[0.037]	[0.037]	[0.037]	[0.037]	[0.037]	[0.037]
Technical environment (dummy)		0.029	0.040	0.028	0.028	0.028	0.027
		[0.028]	[0.028]	[0.028]	[0.028]	[0.028]	[0.028]
Autonomy		0.053***	0.043***	0.052***	0.052***	0.053***	0.052***
		[0.010]	[0.010]	[0.010]	[0.010]	[0.010]	[0.010]
Intensity of competition (dummy)		-0.054	-0.057	-0.057	-0.056	-0.056	-0.057
		[0.037]	[0.037]	[0.037]	[0.037]	[0.037]	[0.037]
Firm size		-0.028***	-0.024***	-0.028***	-0.029***	-0.028***	-0.028***
		[0.006]	[0.006]	[0.006]	[0.006]	[0.006]	[0.006]
Gender (men = 1)	0.179*	0.152*	0.145	0.163*	0.169*	0.169*	0.170*
	[0.099]	[0.092]	[0.096]	[0.091]	[0.091]	[0.092]	[0.092]
Hours of work time	0.002***	0.001	0.001	0.001	0.001	0.001	0.001
	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]
Type of organization (private firm =1)	-0.442***	-0.252***	-0.235***	-0.259***	-0.258***	-0.256***	-0.258***
	[0.053]	[0.057]	[0.055]	[0.057]	[0.057]	[0.057]	[0.057]
Status of the patent (granted = 1)	-0.004	0.027	0.024	0.029	0.028	0.029	0.029
	[0.030]	[0.029]	[0.029]	[0.029]	[0.029]	[0.029]	[0.029]
Number of claims	0.003**	0.001	0.001	0.001	0.001	0.001	0.001
	[0.002]	[0.002]	[0.001]	[0.002]	[0.002]	[0.002]	[0.002]
Geographic region (reference group: central Europe)							
Northern Europe (dummy)	-0.066	-0.137**	-0.103	-0.139**	-0.139**	-0.140**	-0.141**
	[0.067]	[0.064]	[0.064]	[0.064]	[0.064]	[0.064]	[0.064]
Southwestern Europe (dummy)	0.228***	0.074	0.103**	0.063	0.070	0.065	0.063
	[0.051]	[0.051]	[0.050]	[0.051]	[0.051]	[0.051]	[0.051]
U.S. (dummy)	0.271***	0.137***	0.178***	0.135***	0.137***	0.133***	0.133***
	[0.042]	[0.042]	[0.041]	[0.042]	[0.042]	[0.042]	[0.042]
Japan (dummy)	0.092**	0.143***	0.237***	0.143***	0.148***	0.141***	0.143***
	[0.041]	[0.049]	[0.047]	[0.049]	[0.049]	[0.049]	[0.049]
Technological area (reference group: chemistry)							
Elecrical Engineering (dummy)	-0.155***	-0.025	-0.039	-0.021	-0.020	-0.020	-0.019
	[0.042]	[0.043]	[0.043]	[0.043]	[0.043]	[0.043]	[0.043]
Instruments (dummy)	-0.072	0.007	-0.009	0.014	0.013	0.013	0.015
	[0.048]	[0.047]	[0.046]	[0.047]	[0.047]	[0.047]	[0.047]
Process Engineering (dummy)	-0.181***	-0.086**	-0.106**	-0.078*	-0.078*	-0.078*	-0.076*
	[0.042]	[0.043]	[0.043]	[0.043]	[0.043]	[0.043]	[0.043]
Mechanical Engineering (dummy)	-0.147**	-0.094	-0.109*	-0.086	-0.085	-0.087	-0.083
	[0.068]	[0.067]	[0.064]	[0.067]	[0.067]	[0.067]	[0.067]
Constant	3.523***	2.180***	2.008***	2.157***	2.147***	2.148***	2.146***
	[0.119]	[0.167]	[0.168]	[0.167]	[0.167]	[0.167]	[0.167]
Observations	4,138	4,138	4,138	4,138	4,138	4,138	4,138
R-squared	0.050	0.133	0.147	0.136	0.136	0.135	0.136
F test	17.93	23.27	25.39	23.03	22.18	22.07	20.79

Robust standard errors in brackets / *** p<0.01, ** p<0.05, * p<0.1