APPROPRIATING VALUE FROM "LEISURE TIME" INVENTION

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ABSTRACT

This paper investigates how "leisure time" invention contributes to firm innovation. We seek to answer three main questions: (1) How can leisure time invention create value? (2) What motivates leisure time invention? (3) How can firms utilize leisure time invention? First, we examine the degree to which leisure time invention is a market or non-market activity, and propose a simple model connecting the knowledge generated in leisure time invention with the knowledge generated by the firm. Second, drawing on the distinction between direct and indirect utility goods, we contend that there is a higher proportion of direct utility involved in the performance of leisure time invention than is the case for paid inventive activities. Such inventors may also try to achieve material rewards for their efforts – but often, they do not. Third, because leisure time invention is highly motivated by direct utility, attempts to realize its commercial value can pose special challenges. We analyze what contractual arrangements can be implemented to govern the relationship between a firm and an employee who has made an invention of potential interest to the firm in her leisure time. We conclude by discussing some of the implications of the analysis.

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1. Introduction

In the film *October Sky*, a Hollywood version of a true story, four high school students in a West Virginia coal mining town, inspired by the 1957 Russian launching of Sputnik, experiment with their own home made rockets. Made aware of a university fellowship prize offered at a national high school fair in Chicago, they develop an entry to the fair and win the prize. This leads to university fellowships for all four, their escape from a future in the coal mines. While the details of their prize submission are not revealed – Hollywood not being inclined to explain technicalities in films involving scientific achievement – this story raises an important point. Sputnik inspired a rash of rocket building activities among the U.S. teen population, including one of the authors of this paper. None of this inventive activity, as far as the authors are aware, was entered into the U.S. national accounts. Yet in many instances it has inspired career choices, and provided the impetus upon which many scientists were recruited into the U.S. National Aeronautics and Space Administration.

This paper seeks to investigate, in an exploratory manner, how individuals working in their leisure time can contribute to the development of new products, processes, and services – a phenomenon we will call “leisure time” invention. While much has been written about the economic value of unpaid work – a category which includes subsistence production, housework, work in the informal sector of the economy such as industrial piece work, and volunteer work (Beneria, 1999) – none of these scholars include inventive activity in their analyses. Yet there is a great deal of anecdotal information about *de facto* leisure time invention. Examples include a schoolgirl designing a weblog, a father building a remote-controlled toy boat for his child, or a computer nerd helping to develop the Linux operating system.

We were intrigued to look into what motivates people to devote their free time to inventing new products of this type – products that probably will never earn them any money, but that they still find rewarding to invent, and products that could well contribute in ways not yet well understood to innovating firms – and, by implication, to the economy as a whole. We believe that leisure time inventive activity does have important economic value, even if it cannot directly be measured in terms of paid work (present or anticipated).

There has been considerable interest in the literature in the various manifestations of leisure time invention. Scholars have investigated the dynamics of open source software (e.g. Lerner and Tirole, 2005, Weber, 2004), user innovation (e.g. von Hippel, 2005, Harhoff *et al.*, 2003, Franke and Shah, 2003), customer creativity (Berthon *et al*, 1999), “crowd-sourcing” (Howe, 2006, Lakhani *et al.*, 2007), and prize contests like the X-prize (National Academy of Sciences, 2000, Davis and Davis, 2006). But these studies investigate leisure time invention from the demand side. Our interest here lies mainly in the supply side, including the jointness between the leisure time invention and firm inventive activities. Other forms of leisure-time invention have received little or no academic attention. For example, many individuals invent games which they share with friends and family. But because these games are not sold on the market, they remain invisible to the public at large.

Our essay is structured around three main questions. In Section 2, we ask: How can leisure time invention create value? We examine the degree to which leisure time invention is a market or non-market activity, and propose a simple model connecting the knowledge generated in leisure time invention with the knowledge generated by the firm.. In Section 3, we ask: What motivates leisure time invention? Drawing on the distinction between direct and indirect utility goods (Hawrylshyn, 1979), we contend that there is a higher proportion of direct utility involved in the performance of leisure time invention than is the case for paid inventive activities. In other words, people enjoy tinkering, and directly consume the benefits from it. Leisure time inventors may also try to achieve material rewards for their efforts – but often, they do not. Because leisure time invention is highly motivated by direct utility, attempts by firms to realize its commercial value can pose special challenges. Section 4 analyzes what contractual arrangements can be implemented to govern the relationship between a firm and an employee who has made an invention of potential interest to the firm in her leisure time. We conclude by discussing some of the implications of the analysis.

2. How can leisure time invention create value?

Leisure time invention may be defined as inventive activity that takes place outside of the formal labor market, efforts for which the inventor gets neither a wage nor a salary. We begin, in Section 2.1, by presenting the concept informally, and illustrating it by the story of the Wright brothers. In Section 2.2, we formalize the definition by introducing a simple model, variations of which cover the main aspects of leisure time invention. We start by considering the case of an inventor who works both at her place of employment ("market-based") and in her leisure time at home. In this case, her leisure time activity represents a continuation of her inventive efforts at work, but she is not paid for it. We then refine the model to include four further cases:

- Where the inventor is working on something else in her leisure time in which the firm is not (necessarily) interested
- Where two employees in a single firm pursue two types of inventions in their leisure time and utilize each other's knowledge in their pursuit
- Where a firm broadcasts a particular need over the Internet and non-employees compete to fill it, and
- Where employees from different firms pool their knowledge sets in their leisure time to achieve successful invention.

2.1. Invention as a "market" and "non-market" activity

In this paper, we argue that inventive effort can be divided between that effort for which the inventor is paid by an employer (market invention), and that effort which the inventor, individually or as part of a larger group of like-minded agents, makes in her (their) leisure time. Leisure time invention, like a hobby, may be motivated by purely personal enjoyment, and is thus a “non-market” activity. Hawrylshyn (1977) discusses the general problems of measuring non-market activities, without specifically mentioning invention. If we substitute the term “inventive activity” for his term “economic activity,” we can paraphrase Hawrylshyn’s analysis of non-market activities (1977: 79-80) as follows:

- *Proposition One:* Inventive activity comprises only a part of economic activity, but that part is significant enough to merit the attention of scholars.
- *Proposition Two*: Market activities comprise only a part of economic activity. The economic value of many activities fall outside the market, here most notably household work, but also unpaid inventive work done in leisure time.
- *Proposition Three:* Market related inventive activity therefore makes up only a portion of a total societal inventive economic activity.

But the notion of leisure time invention is complex. The leisure time inventor’s intent might instead be to sell or license the rights to her invention to another party. In this case, the inventor is still utilizing her leisure time but on a “market” basis.[3] As we will note, a major challenge for society is to “incentivise” the field of leisure time invention so that these inventions can contribute to the commercialization of new products or services.

Invention refers to the conceptualization and further development of a novel idea. Innovation refers to the commercialization of the invention in the form of a new product, process or service. In this paper, we focus on the invention process. Inventive activity is seen as the practical implementation of a new idea derived from new combinations of knowledge based on “prior art” and “know-how.” By “prior” is meant preceding. “Art” is defined in terms of learning. “Know-how” refers to procedural knowledge: the knowledge of how to perform some task.

The story of the invention of the first airplane provides a striking illustration of the practical implementation of new ideas based on combinations of knowledge involving prior art, and the use of procedural knowledge or know-how. The airplane was developed in the early twentieth century by two brothers, Wilbur and Orville Wright. They were untutored in formal

[3] To take a parallel, a professor might buy a house, use her leisure time to modernize the house, and then ‘flip’ it on the market. The motivation here is market-based, while her activity is leisure time.

engineering skills. Their income came from a very successful printing/bicycle enterprise in Youngstown, Ohio, which alone financed their leisure time activities.[4] An airplane is clearly quite different from a bicycle, but its invention in fact built on many of the brothers' work-related skills. This story demonstrates how inventors can be motivated by both direct and indirect utility, providing a good example of the synergies characteristic of our joint firm and leisure time invention model. (Much of the following can be found in Heinsohn, 2007, but see also U.S. Centennial of Flight Commission, 2004; and Smithsonian Institution, National Air and Space Museum, 2004).

The Wright brothers' invention was to a large degree based on knowledge acquired from others. Otto Lilienthal, a German engineer, had discovered that to give a wing lift, its leading edge had to be curved upward (cambered wing). His experiences with hang gliding, published in magazine articles, inspired the Wright brothers. Octave Chanute, an American engineer, solved the problem of wing structural soundness. He found that by having double decked wings with a Pratt truss (connected by vertical struts for compression, and diagonal wires for tension), sizable wings could be constructed that would not fall apart under pressure. Both the gasoline engine and the propeller had already been invented as well, but would have to be modified to provide air power.

Know-how acquired through experimentation and observation was, in many ways, even more important. For example, the brothers' use of the Lilienthal designs (prior art) for optimum wing camber led to some gliding disasters. These were rectified after the brothers had tested more than 200 model wings in their primitive wind tunnel (the first of its kind in the world). This enabled them to design wings better able to solve the problems of lift and drag.

A major problem concerned executing controlled turns in the air. The airplane had to both turn and at the same time maintain lift under the wings. The two brothers noted how vultures accomplished this manoeuvre by banking in their turns, twisting one wing upward and the other downward. This knowledge, gained through observation of birds in flight, was creatively combined with their knowledge about bicycles and wire strength (light weight bicycles use many wires under tension connecting points on the wheel to tangential points on

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[4] In addition to inventing the airplane, the brothers also took out patents on bicycle design. They were particularly successful in designing and marketing various forms of ultra-light bicycles.

the wheel hub), yielding new forms of know-how which aided them in designing structurally sound biplane wings. It proved critical in their development of the wing warp, and their ability to bank turns in the air. They had found that wings might be warped by applying tension to the diagonal wires of the Pratt truss.

The Wright brothers' early experiments in quantifying wing lift and drag were based first on small test wings mounted on the handlebars of a bicycle, which would be ridden at a particular speed. To this end, they built their wind tunnel, which used a gasoline-powered engine driven fan. This experience, in turn, gave them the know-how as to better construct both gasoline engine and propeller. They then built an aluminum 74 kilogram 12 horse power engine, and the first propeller designed for "screwing through air."[5]

Most of all, the brothers used their bicycle know-how in designing the control system. **Flyer One** carried over the symbiotic relationship between rider and bicycle to that between pilot and airplane. To this end, they designed a hip cradle. The pilot would fly lying down, his hips in the cradle, which was attached to those wing trusses critical to wing warp. Moving hips laterally would apply pressure to the trusses causing the wings to warp and the plane to turn, much as a bicyclist leans to the left or the right to make turns. This leaning also controlled the rudder. Hand levers controlled the elevators. Other pieces of equipment came right out of the bicycle shop. The twin propellers were powered by bicycle chains. The landing gear utilized a bicycle hub to guide **Flyer One's** skids along the take-off track.

Could the Wright brothers have invented the airplane in their leisure time without the skills, perceptions, and know-how developed in their successful bicycle business? Clearly, their invention would have been impossible without the knowledge acquired from experts like Chanute and Lilienthal. But more importantly, the brothers solved the fundamental problems of control in heavier-than-air flight. They might never have succeeded without combining existing outside knowledge based on prior art with knowledge based on experimentation

[5] The engine could have been built by others than the Wright brothers and their mechanic, Charlie Taylor. The reason they designed and built the engine was that they felt they only needed the one model and ordering a single model from another firm would have been costly. The propeller design with its twist towards the tips of the propellers was significant in enabling sufficient thrust to carry the plane into the air. All propellers since the Wright brother's first propellers incorporate the same essential design.

derived from designing, manufacturing, and repairing bicycles. Together, these yielded the knowledge behind their successful invention.

2.2. A simple model

2.2.1. The basic model: Leisure time invention as a continuation of paid work

We start by considering a simplified case of an inventor who works both at her place of employment and in her leisure time at home, where her leisure time activity is a joint product of her inventive efforts at work, but for which she is not paid. We assume that an inventor divides her work on a specific invention into work at her place of employment (market-based), and work at home (leisure time invention, not market-based).

Let time at work inventing be T_w, and T_h represent leisure time at home inventing. Let us consider one firm with I employees. Knowledge is assumed to be quantifiable and discrete, comprising a set of knowledge types. Let us denote each knowledge type as K_n, where $n = 1,...,N$. Each employee possesses some types of knowledge. Denote each employee i's possession of K_n by e_{in}, where $e_{in} = 1$ if the employee possesses that knowledge type, and $e_{in} = 0$ otherwise. If at least one employee possesses a knowledge type, then the firm also possesses that knowledge type. Denote the firm's possession of one type of knowledge, K_n as f_n, where $f_n = max(e_{1n}, \dots , e_{In})$. So, $f_n = 1$ if the firm has that knowledge type, and $f_n = 0$ otherwise. Let h represent some combination of the minimum number of knowledge types necessary for an invention, for example $h = min(K_1, K_2, K_7)$, if knowledge types K_1, K_2 and K_7 are required for the invention. Then if $h=1$ the invention is made; if $h=0$, the invention is not made.

2.2.2. First variation: Leisure time invention in which the firm is not (necessarily) interested

Here, the firm can only develop a small proportion of the very many available subsets of knowledge types. Therefore the firm has to prioritize. Management sorts out the different types of knowledge, separating those it finds valuable from those without value, either due to economic feasibility, or to what it defines as the firm's core competences, or both.

Define the set of all knowledge types as K. Assume subsets of knowledge types K_X , K_Y, and K_Z, where K_X , K_Y, $K_Z \subset K$, and where K_Y, K_Z are the knowledge types available, but for one reason or another are not utilized by the firm, which is concentrating on knowledge type K_X. Let one or more of the firm's employees spend their leisure time developing knowledge types K_Y, and K_Z. We are now considering the impact of leisure time invention in terms of three related types of knowledge: type X, pursued by salaried employees within the firm, and types Y and Z, which are the focus of one or more employees in their leisure time at home.

Assume that management has erred and the minimum knowledge types needed for the firm's invention is $h_X = min(K_{X1}, K_{X2}, K_{Y1})$. The firm effort would then fail. Assume that an employee who has developed knowledge type K_{Y1} in her leisure time, sees the proper solution, and convinces management of its worth. The firm effort would then succeed. Here, it was the leisure time inventive activity which (perhaps unconsciously) led to firm success. Alternatively, assuming that the individual inventor is working on invention $h_Y = min(K_{Y1}, K_{Y2}, K_{X1})$, she can benefit from the knowledge acquired from other colleagues at her workplace. Job skills thus render home-grown invention successful.

2.2.3. Second variation: Leisure time invention where two employees in a single firm pursue two types of inventions and utilize each other's knowledge types

Let two employees working in their leisure time develop knowledge types K_Y, K_z. We are now looking, again, at the impact of leisure time invention in terms of three related types of inventions, type *X* at work for the firm, and types *Y*, and Z, the focus of one or more employees at home in their leisure time – but in this case, the employees communicate their knowledge types to one another. Successful leisure time inventive effort for the two could be expressed as follows

$$h_Y = min(K_{X1}, K_{X2}, K_{Y1}, K_{Y2}, K_{Z1}) = 1 \qquad (1)$$

$$h_Z = min(K_{X1}, K_{Y2}, K_{Y3}, K_{Z2}, K_{Z4},) = 1 \qquad (2)$$

Invention skills and expertise acquired both at work and at home have been successfully combined in the hobby activities of the two leisure time inventors.

And, as an important note, leisure time invention does not need to be successful in order to have an impact. For example, a leisure time inventor pursuing h_Y in *(2)* above, may never acquire the other knowledge types to be successful, but if she acquires K_{Y1}, she can make a useful contribution to collective efforts to solve h_X in the firm variation in section 2.2.2 and to solving her collaborating friends efforts, as shown in expression *(1)* (above).

2.2.4. Third variation: Leisure time invention where a firm broadcasts a particular need and non-employees compete to fill it

While this variation resembles the previous one, it differs in that the required knowledge types for successful invention are outside the firm set of knowledge types, in our basic model (Section 2.2.1). Say management realizes that their employees do not possess the expertise to master knowledge type K_ω and, recognizing this need, are confronted with a choice. They can either invest resources in acquiring this expertise, or they can search for firms or individuals from whom they can purchase it. (This is the source of the current "crowd sourcing" wave, where leisure time inventors or hobbyists play a surprisingly large role, and rewards are offered for successful solutions). These working on their own time have come up with a surprising array of solutions to scientific problems which have stumped multinational giants such a Proctor and Gamble and Boeing.

2.2.5. Fourth variation: Collective leisure time invention

This is a self organising variation of the leisure time invention puzzle. Predominant here are the self organised computer programmers who have invested leisure time in developing programmes such Linux and other open computer languages. Also included in this category are groups of inventors who use their leisure time in order to win one or another well advertised prize contests. Contests which come to mind here include the Ansari-X prize for space flight, the Grainger prize for removing arsenic from drinking water, and the DARPA prize for unmanned vehicle navigation, to which we will return below.

3. What motivates leisure time invention?

The motivations for leisure time invention have many similarities with the motivations for open source software (which also often fall within our definition of leisure time invention). Economists discount altruism as a motive here. They also largely discount classic economic explanations. Referring to the Linux phenomenon, Raymond states flatly: "The 'utility function' Linux hackers is [sic] maximizing is not classically economic, but is the intangible of their own ego satisfaction and reputation among other hackers" (quoted in Lerner and Tirole, 2002: 198).

In contrast, Lerner and Tirole (2002: 212-213) have their own explanation of the open software phenomenon:

> A programmer participates in a project, whether commercial or open source only if he derives a net benefit (broadly defined) from engaging in the activity. The net benefit is equal to the immediate payoff (current benefit minus current cost) plus the delayed payoff (delayed benefit minus delayed cost)… The delayed reward covers two distinct, although hard-to-distinguish, incentives. The *career concern incentive* refers to future job offers, shares in commercial open source-based companies or future access to the venture capital market. The *ego gratification incentive* stems from a desire for peer recognition. Probably most programmers respond to both incentives.

Lerner and Tirole then explore various facets of the open source software movement: Leadership, the "alumni effect," customization and bug-fixing benefits, control of the developer's economic environment are all assigned a role in the scheme of things. In conclusion, they state that the answer to their question is to be found in the "literatures on 'career concerns' and on competitive strategies (*Ibid*.: 231)."

While we largely agree with Lerner and Tirole's analysis of leisure time invention, we believe it does not fully capture the motivations of these individuals. We question whether it can sufficiently explain our own discussions with leisure time inventors who uniformly downplay the role of immediate and long range net benefits associated with their efforts. Instead, these inventors focus on the challenges involved in finding a solution to a problem or on the sheer joy of tinkering. Nor do Lerner and Tirole explain why leisure time inventors often accept little or no economic compensation, when others seek to utilize their inventions. Either leisure time inventors are not really aware of their fundamental economic motivations, or there is some other determining element here. In contrast to Lerner and Tirole's analysis (which relies solely on measuring indirect utility), we turn to the leisure time literature's emphasis on both direct and indirect utility maximization. We see leisure time inventor motivation as being a complex combination of these two classic economic concepts.

3.1. The significance of leisure time invention for the inventor-agent

By regarding leisure time invention as a portion of an individual's leisure time, in line with the three propositions in section 2.1, we regard the individual inventor-agent as maximizing her utility. She trades time spent in developing an invention with other leisure time activities, such as watching television, playing tennis, or dining at exclusive restaurants. Here, Hawrylshyn's (1977) distinction between direct utility goods and indirect utility goods is useful. The leisure time inventor maximizes her utility directly by consuming goods like watching television. At the same time, she maximizes her utility by producing goods. These can include the production of basic commodities (like watching the children, preparing food), of commodities that enable her enjoyment of the consumption of basic commodities (putting the children to bed so as to see a television program in peace and quiet), or that ease her work load in producing basic commodity goods (building a summer cabin to enjoy her vacations). These are all indirect utility goods. Producing these goods enables the individual to enjoy direct utility goods (like the television program, or the summer vacation).

Leisure time invention involves non-paid utility maximization in both senses, and in both non-market and market contexts. Suppose our leisure time inventor derives pleasure from tinkering with her invention concept (direct utility) and plans to use the invention as a gift to her husband (indirect utility). This inventor is engaging in non-market leisure time activities. Suppose, alternatively, that she both enjoys tinkering (direct utility) and intends to patent and license her invention to enjoy a future income stream from her leisure time activity (indirect utility). She is then engaging in invention in her leisure time, but her efforts involve a combination of non-market (direct utility) and market (indirect utility) efforts.

What is critical about these distinctions is that they underline the ambivalence surrounding leisure time invention. Key here is the direct utility which the leisure time inventor derives from her efforts, successful or unsuccessful. *Ceteris paribus,* if the entire inventive effort is prompted by a form of direct utility, the "reward" for invention is the satisfactory solution of a problem *per se*. Such an inventor will be more likely to share her results with others, and less likely to enter into a dollar-for-dollar patenting and licensing effort. The higher the indirect utility involved, the less the reward for solving the problem *per se*, and the more meaningful the *ex post* return on the inventive effort. While there are many intervening variables here, one can draw a parallel with university scientists who enjoy doing research, but are often not interested in patenting and licensing the resulting inventions. Rather, these scientists are more susceptible to corporate blandishments which enhance their direct utility (bigger and better laboratories, research grants, more research assistance).

3.2 The significance of leisure time non-market invention for the firm

Two varieties of leisure time invention are significant for the firm: that undertaken by the firm's employees, and that undertaken by third parties (whether by the firm's customers or other societal stakeholders) that is relevant to the firm's innovation activities. Unlike the individual home tinkerer, the firm has an interest in converting this leisure time non-market invention to market-oriented economic use.

For example, if the Wright brothers had been employees of another bicycle firm (i.e. a firm not owned by them), would their employer have allowed the multifarious activities involved in designing and flying **Flyer One,** even if these activities did not directly impinge on their productivity in the bicycle shop? This can be analyzed using the model presented in Section 2.2. The jointness of knowledge sets illustrated by inventions *X*, *Y*, and *Z,* and their relationship to invention at the firm level, leads to the following critical management predicament:

Firstly, it is not a given that inventions *X, Y* and *Z* are based on joint knowledge sets. Secondly, even if they were, it is not a given that inventions *Y* or *Z* have a commercial application. And, thirdly, even if *Y* and *Z* had commercial applications, these would not necessarily fit into the firm's core competences. In each case, invention by the firm's employees in their leisure time should perhaps be confined to developing those types of knowledge relevant to invention *X*. Management would encourage only leisure time activities directly relevant to invention *X*, that could increase the expertise necessary to develop subsets of knowledge, K_{Y1}, K_{Z1}. In this manner, the firm's assessment of the commercial value of other invention activities would prevail over its possible interest in developing any of these, even if they became available.

Alternatively, management might decide that the acquisition of less relevant knowledge types, such as K_{Y2}, K_{Z4} , could lead to more productive invention within the firm. This would lead them to encourage leisure time inventive activity in the home, in the anticipation that related types of knowledge thereby developed would work to the firm's longer run, overall competitive advantage.

As regards leisure time invention relevant to the firm undertaken by that firm's customers or other societal stakeholders, management faces a variation of the same set of problems. On the one hand, managers would like to remain open to its potential commercial applicability; but on the other, they would not wish to waste resources in what might be a fruitless exercise.

3.3. Leisure time invention and the self organising group

Self organising inventing groups can take two major forms. The first are leisure time inventors who have worked together on a specific technology for a long time, and found that sharing knowledge is more profitable than not sharing. An example is open source software. The second category refers to groups of individuals organized to win a prize.

In Lerner and Tirole's (2002) analysis of the institutional arrangements behind the open software phenomenon, they note that the early development of computer operating systems was dominated by institutions which were either essentially academic, or firms with a "great deal of autonomy (*Ibid*: 200)." Sharing of computer code was then quite common, with no attempt to define property rights to the languages involved. In 1983, the Free Software Foundation was established to promote varieties of software without cost to the users. An end to this means was the development of the General Public License (GPL). Diffusion of this open access system accelerated with developments in the Internet and the introduction of the Linux language. Interestingly enough, Lerner and Tirole (2002: 220) note that the "fun" and "crowd" effects had a stimulating influence on developments:

> Open source projects have trouble attracting people initially unless they leave fun challenges "up for grabs." On the other hand, the more programmers an open source projects attracts, the more quickly the fun activities are completed. The reason why projects need not burn out once they grow in ranks is that the "fixed cost" that individual programmers incur when the first contribute to the project is sunk and so the marginal cost of continuing to contribute is smaller than the initial cost of contributing.

The institutional self organizing arrangements for prize contests are somewhat different. An example is the DARPA 131.6 mile robot Mohave prize, in which a robot vehicle had to navigate various obstacles (including tunnels) within a ten hour time frame in order to win a $10,000,000 prize. It attracted no fewer than 43 teams, many from university engineering faculties. Stanford took first prize with "Stanley". The next two winners, named "Sandstorm" and "Highlander," were backed by Carnegie Mellon. The fourth, "Kat5" was backed by a Tulane University team sponsored by an insurance company Gray Insurance. Other entrants read like a "who's who" of U.S. engineering schools (among the 20 other university teams were Cornell, Virginia Tech, Auburn, Tulane, and Ohio State). All the non-university teams, with names such as “Overbot” and “Team Banzai,” consisted largely of engineers working for other firms, but who dedicated their free time to the prize competition.

These and other contests, such as the Ansari-X Prize for successful flight to the edge of space, and the Grainger Prize for a low-cost method of removing arsenic from drinking water, have been dominated by enthusiasts, often organized into “mom and pop” organizations. They typically comprise professional engineers working in their leisure time, and university faculties, desiring to use their collective knowledge and bits of know-how in a practical manner. Commercial firms have tended to participate only indirectly. Firms associated with DARPA prize, for example, were (1) small, (2) essentially team sponsors, (3) contributing the vehicles or computer programs involved, or most often all three of the above.

A related incentive system is the development of internet business sites where firms post research problems they have been unable to solve and promise rewards (prizes) to those part time inventors who solve the problems for them, the phenomenon earlier referred to as “crowd-sourcing” Most notable is the InnoCentive.com site devised by Eli Lilly in 2001 to connect with outside company talent. This site has been thrown open to other firms who can post their problems to some 80,000 scientists in over 150 countries (Lakhani *et al.* 2007: 4). Firms using this site now include Boeing, DuPont, and Procter and Gamble. Particular important are rewards offered from “reduce to practice” forms of know-how. Successful solvers get paid anywhere from $10,000 to $100,000. Although Howe describes these as “hobbyists” they are, in fact, leisure time inventors:

> The solvers are not who you might expect. Many are hobbyists working from their proverbial garage, like the University of Dallas undergrad who came up with a chemical to use in art restoration, or the Cary, North Carolina, patent lawyer who devised a novel way to mix large batches of chemical compounds (Howe, 2006: 5).[6]

The internet also facilitates supply-push leisure time invention. The computer program, ‘Second Life,’ which first opened in 2002, allows participants to create a 3-D virtual world

[6] Nor is Innocentive alone, Procter and Gamble have established two networking sites: YourEncore gives companies access to retired scientists for specific company assignments, and NineSigma is “an online marketplace for innovations, matching seeker companies with solvers in a marketplace similar to InnoCentive (*Ibid*).” What is interesting about all these initiatives is that they are response to the problems confronting the firm, as described in our simple model in section 2.

and share their virtual world (digital creation) with other users. This program has led to leisure time inventors' placing the designs of their inventions on the net where they can be visited by others. An additional attraction offered by 'Second Life' is 'The Marketplace' which allows for the buying and selling of the attractions offered in 'The Creations.' This invention/design commerce uses the Linden Dollar, and can be converted to U.S. dollars on online Linden Dollar exchanges.

3.4. The role of intellectual property rights

By patenting their new products and processes, leisure time inventors can ensure potential buyers that the invention has not been patented by someone else, and can be legally enforced. Such patents can also serve as signals of value to would-be investors and corporate partners, and the basis for licensing agreements (e.g. Cohen *et al.*, 2000, Davis, 2004). While there are no studies of patent use by leisure time inventions, in our opinion, while the leisure time inventor may take out a patent or two, patenting is probably of little importance here.

First, patenting is costly. In particular, the mechanisms for collecting and enforcing patent rights, and licensing royalty income, are complex and impose high transaction costs. The patent covering the Wright brothers invention of the airplane, for example, primarily rested on their warped wing design, but was extended to cover like devices like the aileron devised by Curtis. The patent was deemed not effective in Germany and France. In the U.S., where the Wright patent rights were upheld, the brothers were involved in such long and costly litigation that it was thought that Wilbur's death from pneumonia in 1912 had been provoked by the stress of the brothers' lawsuits.

There are two further reasons why patents may be unsuitable for leisure time invention. For one thing, patents specifically reward indirect utility. To the degree that the inventor is motivated by curiosity, or the love of creating something new, she will not find the guarantee of exclusive rights enshrined in the patent system particularly motivating. She may, perhaps, wish to share the fruits of her inventive efforts freely with others. Moreover, a great deal of leisure time invention is carried out by two or more inventors working together, sometimes in cooperation with inventors in a firm, sometimes not. Two of the variants of our model – broadcasting, and self-organizing invention – may involve quite large numbers of inventors, some of whom work independently of each other, and who may or may not cooperate with each other. The patent system is ill-equipped to govern this type of invention.

There are other, less costly means of securing appropriability. One of the authors of this paper was approached by an engineer who had developed a new, electronic form of solitaire and wished to earn money from his invention. Her advice was to put the game on his home page, apply for a trademark and a domain name, protect the source code by technically blocking access to those parts of the code he didn't want copied, apply for design protection, and work to attract enough players so that advertisers would pay him to have their logos on his solitaire site.

Leisure time inventors can also make it possible for satisfied players to pay them directly via an account on their home page. An example is John McAfee, an engineer who dealt with virus problems for Lockheed. He developed a virus fix and posted it on a computer bulletin board in 1989. McAfee asked the people who downloaded it to send him whatever money they thought his invention was worth. Within a year, he had made $5 million! (Shapiro and Varian, 1999: 90).

4. Firm utilization of leisure time invention

Section 3.2 touched briefly on the significance of leisure time invention for the firm, but did not discuss how a firm can utilize leisure time invention. One can approach this issue through the device of a worker-employer contract.

An employee with a specialized piece of potentially commercially valuable knowledge developed in her leisure time is in possession of private information. She is confronted with a set of choices. She can reveal the information to her employer or keep it to herself, with a view to either starting her own firm, or selling the information to a competing firm. In both cases, she will leave the firm. Alternatively, she can reveal the information to her employer in the hopes of a reward if it is integrated in an internal project, or forms the basis for a firm 'spin-off.' Since her information is a function of her leisure hobby at home, her efforts are unobserved by her employer.

For simplicity's sake, we assume that her employer belongs to one of two categories of firm: a category one firm with a low cost technology whose products or services are unprotected by a strict set of intellectual property rights, and a category two firm with a high cost technology protected by a set of intellectual property rights. The managers of both firms have two problems: picking "winners" from various combinations of firm knowledge types, and keeping inventive workers from leaving the firm, either to start up their own firms or to convey their know-hows to competitors (See, for example, Anton and Yao, 1995; Pakes and Nitzan, 1983; Rosen, 1972; and Moen, 2005).

To these problems we add the two dilemmas of how the firm can derive benefits from worker leisure time know-how: inducing workers to share their private information about their potentially valuable leisure time knowledge; and eliminating what might be termed 'leisure time shirking behaviour' (in which the worker uses firm time and assets to pursue a fruitless line of endeavour connected with her hobby).

Employers in both categories of firms are in a position to offer their workers *ex ante* incomplete contracts, typically contracts with trailer clauses (giving ownership of an invention to the employer if the inventor leaves the firm for a specified period, after which it reverts to the employee), shop rights clauses (conferring ownership of patents to the discoverer simultaneously with conveying a nonexclusive, non assignable and royalty-free license to use the invention to the employer), and other forms of incentive contracts contingent on the firm management's objectives (Aghion and Tirole, 1994: 1187).[7] Yet there are a range of contractual alternatives not available to category one firms. (For example, contracts with shop rights clauses cannot be a feasible alternative in the absence of patent rights).

[7] Chief among these are contracts with performance bonuses. There are also instances of contracts awarding successful a fixed percentage of the resulting sales revenues (Milgrom and Roberts, 1992, pp. 399-400).

Pakes and Nitzan (1983); and Rosen (1972) suggest two overlapping explanations for successful firm retention of talented workers. Pakes and Nitzan argue that an employer can always make a more attractive offer to a worker with a profitable idea, which can trump any putative worker advantage from leaving the firm and starting up her own company, or selling her idea to a third party. They note that if the innovation makes the firm a true monopolist, it will never pay for the worker and firm to split, in that the sum of rents in a duopoly market would be less than that in a monopoly market. It is therefore in the interests of both to find an internal solution.[8] There are two consequences stemming from this argument. Firstly, those firms where talented workers may be tempted to leave and start on their own will be more likely to patent. Secondly, as a result, such firms will utilize incentive contracts to retain their talented human capital. Both of these consequences have been confirmed empirically (Kim and Marschke, 2001).

Rosen (1972) argues that on the job "learning" should be taken into account when looking at worker retention. Such learning is part of an employment bundle of rights and is valued by the worker, particularly since such learning leads to better jobs and skills. Over time, workers will divide into the 'able learners' and the 'others,' leading to a form of ability distortion.

An implication of both interpretations should be that workers with skilled know-how will be content to commence their employment at low wages, in the anticipation that over time, their wages will increase as they acquire further know-how, a form of bonding. Empirical investigations have confirmed this assertion. Balkin and Gomez-Meija's (1985) investigation of 105 firms in the Route 128 belt around Boston found that incentive pay schemes in (category two) high tech enterprises are more common than in their (category one) lower tech counterparts. Personnel key to these firms' start-ups are given long term stock options. These findings have been further confirmed by Moen's (2005: 81-114) study of the technical staff of the Norwegian machinery and equipment industries.

[8] There exists a debate as to whether the same situation would occur if there were several workers with the same know-how. See Combes and Duranton (2001).

The problems of retention for the category one firms without IPR walls are of a different order. Given that these firms rely on unprotected knowledge for their competitive advantage, appropriation of a new combination of knowledge types is relatively easy, and the chances that a leisure time inventor would have her ideas appropriated by her firm without compensation are relatively high. Here, commencing with one's own start-up would be the more attractive alternative. One would expect under the circumstances, such firms would rely heavily on trailer clauses in their employment contracts.[9]

Between these two firm categories are firms with many different combinations of capital intensity, skilled and unskilled workers, and different degrees of IPR protection. Clearly, many problems of worker retention can be countered by appropriate employment contract design. Furthermore, there are significant transaction costs attached to outside alternatives which a leisure time inventor could do without, both in terms of selling her idea to another firm, or starting up her own enterprise.

To the problem of retention, we add the leisure time dilemmas introduced above. With regard to the first dilemma, the revelation of potentially valuable privately held leisure time knowledge can be procured by the same incentive contracts designed to enhance firm retention of technical staff. In both cases, the objective is to prevent worker exploitation of her privately held know-how in her own start-up, or in conjunction with a competitor. In both, worker contractual incentives should facilitate workers sharing their privately held information in return for higher compensation.

The second dilemma concerns distinguishing between the acquisition of knowledge more appropriate to the worker's leisure time, and those with more direct relevance to their place of employment, which we have termed 'leisure time shirking.' This 'jointness' problem, endemic to our definition of leisure time invention, can be addressed in two manners. The first, "monitoring," the economic solution to shirking (Alchian and Demsetz, 1972), no doubt

[9] Oddly enough, we could not find any empirical studies to confirm this impression. There are two possible reasons for this: the use of 'trailer clauses' is so common in both high tech/patent protected industries and low tech/unprotected industries that a contractual pattern is not discernable; or it remains an area for empirical investigation.

can be applied equally well to assuring that inappropriate leisure time inventive activity is minimized in the firm workplace. However, defining of what constitutes ‘appropriate’ makes effective monitoring extremely difficult.

A second approach would be to legitimatize certain leisure time inventive activities within the firm. Given that engineers, scientists and other highly skilled workers initially prefer low wage jobs with higher learning potential (and consequently higher future wages), a solution might be to package what some workers would be doing in their leisure time into the firm worker learning experience. Stern (1999:28), in an analysis of research biologists working in biotech firms, found that researchers allowed to engage in “open science” were willing to “pay a compensating wage differential” for the possibility to do so. Since greater freedom to engage in open science is a form of direct utility, Stern’s findings might have implications for leisure time invention. Workplace generation of what would otherwise be leisure time know-how need not necessarily have negative consequences for a firm’s bottom line, if workers are prepared to settle for less in return for increased learning experience.

5. Conclusion

We have argued, in this paper, that leisure time invention is more important than is generally realized, since the types of knowledge derived from leisure time invention are characterised by jointness with those acquired in the formal workplace. We took issue with the conventional economic approach to the analysis of “puzzling” forms of leisure time invention like open source software, where the motivation is seen as some form of future market compensation. We argued, instead, that leisure time invention can have some of the characteristics of a hobby (“tinkering”) or an artistic pursuit, which yields pleasure to the inventor over and above any expectation of future reward. We contended, further, that while market imperfections make it difficult to govern the relationship between the leisure time inventor and an interested firm, solutions do exist.

Several implications of our arguments might be mentioned. Managers of companies can use the insights from this paper to develop a more nuanced view of innovation, where formal systems such as R&D laboratories and patents can usefully be supplemented by engaging the talents and enthusiasm of leisure time inventors. This paper also provides yet another reason to preserve the independence of university researchers and their ability to engage in research projects of their own choice. While the results of this research cannot necessarily be patented, it still can have enormous value to companies. That leisure time invention may actually be increasing in importance is suggested by the great ferment created in the business world in recent years by the introduction of more open innovation models such as creative commons licensing, and the practices of free-revealing and crowd-sourcing.

A fundamental issue not addressed in this paper concerns how leisure time invention can be measured. The value of leisure time invention does not feature in a country's national accounts. As a result, GNP does not necessarily represent the level of inventive talent in a country. One implication is that comparisons of countries, in terms of their innovativeness, that rely on formal measures such as the number of patents applied for, may be misleading. Another is that countries can potentially make more of the value created by leisure time inventors. Specific industrial policy initiatives might be implemented to this end. To what extent, for example, could prize contests provide a better incentive system to realize the benefits of leisure time invention?

Future research could also address the contractual issues that arise in relation to the other kinds of leisure time invention discussed in Section 2: where two firm employees pursue two types of inventions and utilize each other's knowledges, where the firm broadcasts a particular need and non-employees compete to fill it, and where leisure time invention occurs within the self-organizing group. For example, we argued in Section 4 that firms might have an interest in encouraging employee leisure time invention, even if the benefits do not accrue to them. But what happens if a competing firm acquires the patent rights to the leisure time invention?

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