COMMUNITY-BASED INNOVATION & PRODUCT DEVELOPMENT:
FINDINGS FROM OPEN SOURCE SOFTWARE AND CONSUMER SPORTING GOODS

by

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Submitted to the Alfred P. Sloan School of Management
In Partial Fulfillment of the Requirements for the Degree of

DOCTOR OF PHILOSOPHY

at the

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

June 2003

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Abstract

Academics and practitioners have long been interested in understanding the sources and causes of innovative activity and the relationship between innovation and industrial change. Existing theory assumes innovative activity to be the domain of firms and research institutions, and commercial activity to be the domain of firms and entrepreneurially-minded individuals. Work in this tradition finds it difficult to explain the emergence of new fields and technological trajectories. This thesis suggests and provides evidence for the idea that social activity may precede and heavily influence both firm and market formation via the innovative activities that take place within user "communities."

"Communities" are composed of loosely-affiliated individuals with common interests. They are characterized by a lack of formal coordination and the free flow of information. These characteristics allow for rich information and feedback and the matching of problems with individuals who possess the ideas and means to solve them. Due to the varied skills and needs of the individuals involved, user communities are well-equipped to identify and solve a wide range of design problems. The "many hands" of communities act as an innovation development and selection process operating largely independent of the visible hands of firms and the invisible hand of markets.

Each essay in the thesis investigates the impact of community-based innovation and product development process on a different level. Essay 1 discusses the impact of user-innovators and their communities on firm and industry formation; Essay 2 examines the inner-workings of four formally-organized communities; Essays 3 and 4 discuss the individual-level motivations that drive community participation. Evidence is drawn from three unique data sets in the fields of commercial sports equipment and software.
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CHAPTER 1

USERS & THEIR COMMUNITIES AS AGENTS OF PRODUCT & MARKET CHANGE: FROM INNOVATION TO FIRM FORMATION IN THE WINDSURFING, SKATEBOARDING, AND SNOWBOARDING INDUSTRIES

Abstract

Academics and practitioners have long been interested in understanding the sources and causes of innovative activity and the relationship between innovation and industrial change. Existing theory assumes innovative activity to be the domain of firms and research institutions, and commercial activity to be the domain of firms and entrepreneurially-minded individuals. Work in this tradition finds it difficult to explain the emergence of new fields and technological trajectories. This paper highlights the idea that social activity may precede and heavily influence both firm and market formation via the innovative activities that take place among loosely affiliated individuals sharing common interests ("communities").

Based on an inductive study of the innovation and commercialization histories of 57 key skateboarding, snowboarding, and windsurfing equipment innovations, this paper finds that (1) User-innovators often receive rich feedback from others with related interests and expertise. This feedback not only helps improve the innovation, but may also be used to make commercialization decisions regarding the innovations. That is, "communities" may serve as an effective development and selection mechanism for user-innovations. (2) User-innovators may start firms in order to appropriate financial benefits from their innovation. This view is unique in that it shows that a significant portion of innovation development and selection activity may be organized outside the boundaries of firms, markets, and research institutions. Firms (and markets) may be the consequence, not the cause, of innovation. A process model highlighting the role of user-innovators and their communities is also presented.
Section 1.1: Introduction

A number of empirical studies find that a relatively large number of firms, many of them new entrants, compete during the early or “fluid” phase of a product’s development (Abernathy and Utterback 1978; Gort and Klepper 1982; Tushman and Anderson 1986; Utterback 1994, for data from several studies). During this period, performance criteria for new products are not well defined and customer needs are addressed through a variety of different product designs. New and existing firms, it is argued, live in a context characterized by high uncertainty regarding technological alternatives and customer demand. R&D is necessary; the search for new information and learning in the process of technical development are critical components of the firm’s R&D function (Nelson and Winter 1982). At the same time, customer purchase and use of the product is critical: at this stage highly salient information about the requirements of the context and the relative value of alternative approaches can be generated only through use (Alexander 1964; Clark 1985)\(^1\).

Despite the treacherous environment, more and more firms enter the product space and engage in R&D activities. Where do these firms come from and how do they choose ideas to exploit? To date, research has focused on two sources: existing firms that move from their current product areas and “entrepreneurial” firms created in response to financial opportunities. Here a third source that has been neglected in the literature is discussed: firms that are formed by user-innovators.

We know that users innovate (Enos 1962; Knight 1963; von Hippel 1988; Kline and Pinch 1996), but the mechanisms by which their innovations (and the preferences underlying those innovations) are communicated to the market and eventually commercialized have not been fully explored. The existing literature focuses primarily on the idea that manufacturers of existing or related equipment find out about user-

\(^1\) Both the absence of knowledge about the technology itself and a limited understanding of the emerging use context contribute to the design challenge faced by a firm’s engineers. Clark (1985) points out that Arrow’s “fundamental paradox of information demand” applies: without customer purchase and use of a product a firm’s engineers and employees are unable to acquire information about the product technology and how well the product satisfies consumer preferences.
innovations, refine them, and introduce them to the commercial market. But in theory and in fact, user-innovators may commercialize their own innovations.

What selection mechanisms help the user-innovator decide if it makes sense to commercialize his or her innovation? This paper suggests and provides evidence for the idea that there is an innovation development and selection process operating in user “communities” that is independent of the visible hand of firms and the invisible hand of markets.

“Communities” are composed of loosely-affiliated individuals with common interests. They are characterized by a lack of formal coordination and the free flow of information. These characteristics allow for rich information and feedback and the matching of problems with individuals who possess the ideas and means to solve them. Due to the varied skills and needs of the individuals involved, user communities are well-equipped to identify and solve a wide range of design problems.

Many user-innovators obtain innovation-related assistance and feedback via participation in communities. These communities operate in a particular area; e.g. scientists may consult with other scientists using similar equipment or having related needs; skateboarders may consult with other skateboarding enthusiasts. A user-innovator may choose to share her idea with others and subsequently be introduced to others with related interests. News of the innovation and its uses may spread and catch the attention of others, thus generating more interest and greater usage. Communication and development costs are borne largely by those who use the product. The user-innovator may begin producing copies of the innovation for those unwilling or unable to produce their own. He or she may eventually even start a firm to produce the innovation for sale to others. Other users, existing manufacturers, or employees of existing manufacturers may also observe the same information and take steps to commercialize the same innovation.
The idea that firms may sometimes be the consequence, not the cause, of innovation is surprising, but follows from the observation that early user-innovators created firms after prototyping the innovation and receiving feedback from a user community\(^2\). Sociological theory has long trumpeted the idea that social activity precedes economic activity, but the case has been difficult to make in many areas. The data on the windsurfing, snowboarding, and skateboarding industries presented here begin to make that case in the context of innovation. General sociability leads to the spread and refinement of innovative ideas and in the process begins to create demand – a market - for a novel product. Firms result as a consequence of this process. This view is consistent with the transaction cost literature (Coase 1937; Stigler 1951). Creating a new firm is costly, thus someone must believe that an innovation or idea has the ability to support a profitable business before creating a firm. In the case of truly novel products, it does not necessarily make sense for firms to innovate and then attempt to create a market or sub-culture to consume the new product.

The paper is structured as follows. The existing literature on user-innovations and the impact of user preferences on market structure is reviewed in Section 1.2. The research sample and inductive methods are described in Section 1.3. Section 1.4 reports research findings with respect to the functional sources of innovation; the identity of those observed to have developed important innovations; and the means used by innovators to appropriate benefit from their innovations. These findings are discussed in Section 1.5. A process model of community-based user-innovation and its implications are discussed in Section 1.6. Section 1.7 concludes.

\(^2\) In its extreme this view would suggest that firms, both new and existing, may serve primarily to manufacture innovations for and further develop the mass market. Reality is somewhere between this view and the traditional notion: innovation occurs within firms and in use environments both internal and external to firms.
Section 1.2: Literature Review

Consumer preferences play an important role in standard economic theory; where these preferences come from, however, is generally considered outside the realm of inquiry. In the context of innovation and technical change the issue of if and how preferences change must be addressed. Much of the innovation management literature identifies firms and entrepreneurs as the primary agents of product change and economic progress (Figure 1-1) (Schumpeter 1934; Nelson and Winter 1977; Dosi 1982). Under this view, firms are motivated by profits and thus invest in research and development in order to create new products for consumers\(^3\). As the instigators of change, it is incumbent upon firms to either educate the consumer to want what they produce or identify and satisfy latent customer needs.

"Yet innovations in the economic system do not as a rule take place in such a way that first new wants arise spontaneously in consumers and then the productive apparatus swings through their pressure.... It is, however, the producer who as a rule initiates economic change, and consumers are educated by him if necessary; they are, as it were, taught to want new things or things which differ in some respect or other from those which they have been in the habit of using (Schumpeter 1934).”

Under this conceptualization, the consumer’s role is a passive one: producers, not consumers, innovate and consumer preferences either do not change without producer

---

\(^3\) If one views innovation solely as the product of firms, than firms must have a choice as to when to invest in activities that will produce innovations. Economists have long argued that the rate of innovation in an industry is a function of market structure (Schumpeter 1950). Schumpeter argues that only oligopolists have the financial resources necessary to finance innovation and have the market power to pass the costs of innovation on to the consumer. Other economists have argued the opposite: that there is an incentive to innovate only when the market is characterized by competition between a large number of firms (Stigler 1951; Dasgupta and Stiglitz 1980). When many firms compete, there is a continual quest for product innovation and the single mass market tends to break up into a number of segments, each representing a slightly different taste. Competition thus creates innovation and diversity, while oligopolistic competition creates a homogenous product. There is little incentive for oligopolists to innovate or to increase the range of alternative products marketed because each firm is trying to capture a larger share of the mass market—to do so, they must produce what pleases the most without offending any major group of customers. The debate continues, but evidence suggests that oligopolistic competition within industries reduces innovation and results in highly homogenous products (Scherer 1970; Scherer and Ross 1990).
influence. The consumer merely chooses to make or not make a purchase based on price and comparison with other products and services.

The following sub-sections present evidence that runs counter to this passive representation of the consumer from three streams of literature: user-innovation, organizational sociology, and community-based innovation and peer production. The literature on user-innovation focuses on the empirical reality that a great deal of innovation comes from “consumers.” The organizational sociology literature focuses on the various and unexpected ways in which consumption preferences might affect industry structure. The community-based innovation and peer production literature is just developing and is based on the observation that individuals are organizing and taking part in innovation and product development activities for the goods they desire.
FIGURE 1-1:
DOMINANT VIEW OF THE RELATIONSHIP BETWEEN
INNOVATION, FIRMS AND CHANGES IN USER PREFERENCES

New product ideas generated by firms (or entrepreneurs)*

Firms educate potential consumers and introduce new products to the market

Consumers purchase and use product

* Technology-push, demand-pull (via the market signals of price and quantity), and evolutionary arguments make this assumption (see Dosi 1982)
1.2.1 User-Innovation

In stark contrast to the consumer behaviors prescribed by the innovation model described above, there exists substantial evidence that the preferences of at least some consumers are changing independent of producer action and are being addressed by the consumers themselves. This evidence takes the form of documentation of innovations made by consumers, or users, as they are called in the literature.

Individual users often experience a need or desire not satisfied by existing products (Alexander 1964; Clark 1985; Norman 1990)\(^4\). In fact, frustration with the inadequacy of products is a common and universal experience that many readers are likely to have shared. A few individuals - among the many who experience needs - design and build a novel piece of equipment, produce a service, or create a technique to satisfy their need or desire. They are not affiliated with manufacturers or providers of similar equipment, services, or techniques.

Studies documenting user-innovation appear in a variety of places and representative examples are discussed in this section. The history and sociology of science, history, and innovation management literatures document the phenomenon of user-innovation in fields as diverse as automobiles (Kline and Pinch 1996; Franz 1999), chemical and petroleum processing (Enos 1962; Freeman 1968), electronic components (VanderWerf 1984; Haring 2002), scientific instruments (Riggs and Hippel 1994), semiconductors (von Hippel 1988), and sports equipment (Luthje 2000; Franke and Shah 2003). Users are the source of many commercially important innovations (Table 1-1) and many users engage in innovative activities, the products of which they – and often others - use (Table 1-2).

\(^4\) According to Alexander (1964) Unsatisfied needs will always exist because there is always some distance between what one has and an ideal product design.
TABLE 1-1:
MANY IMPORTANT INDUSTRIAL PRODUCT INNOVATIONS ARE DEVELOPED BY USERS*

<table>
<thead>
<tr>
<th>Product Area</th>
<th>Source of Innovation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>User</td>
</tr>
<tr>
<td>Petroleum processing</td>
<td>43%</td>
</tr>
<tr>
<td>Enos (1962)</td>
<td></td>
</tr>
<tr>
<td>Computer innovations 1944-1962</td>
<td>26%</td>
</tr>
<tr>
<td>Knight (1963)</td>
<td></td>
</tr>
<tr>
<td>Chemical processes and process equipment</td>
<td>70%</td>
</tr>
<tr>
<td>Freeman (1968)</td>
<td></td>
</tr>
<tr>
<td>Scientific instruments</td>
<td>76%</td>
</tr>
<tr>
<td>von Hippel (1976)</td>
<td></td>
</tr>
<tr>
<td>Semiconductor and electronics subassembly</td>
<td>67%</td>
</tr>
<tr>
<td>manufacturing equipment</td>
<td></td>
</tr>
<tr>
<td>von Hippel (1977)</td>
<td></td>
</tr>
<tr>
<td>Wirestripping and connector attachment equipment</td>
<td>11%</td>
</tr>
<tr>
<td>VanderWerf (1982)</td>
<td></td>
</tr>
</tbody>
</table>

* These studies focus on industrial product innovations and thus they find that users within firms and research institutions innovate. No known similar studies of consumer products innovations have been conducted.

b Attributed to independent inventors/invention development companies.
TABLE 1-2: A LARGE FRACTION OF USERS INNOVATE

<table>
<thead>
<tr>
<th>Product Area</th>
<th>Innovating for Own Use</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Percent</td>
</tr>
<tr>
<td><strong>Industrial Products</strong></td>
<td></td>
</tr>
<tr>
<td>Printed circuit CAD software</td>
<td>24%</td>
</tr>
<tr>
<td><em>Urban and von Hippel (1988)</em></td>
<td></td>
</tr>
<tr>
<td>Library information systems</td>
<td>26%</td>
</tr>
<tr>
<td><em>Morrison, Roberts, and von Hippel (2000)</em></td>
<td></td>
</tr>
<tr>
<td>Apache OS server software security features</td>
<td>19%</td>
</tr>
<tr>
<td><em>Franke &amp; von Hippel (2002)</em></td>
<td></td>
</tr>
<tr>
<td><strong>Industrial &amp; Consumer Products</strong></td>
<td></td>
</tr>
<tr>
<td>Automobiles on US farms</td>
<td>NA</td>
</tr>
<tr>
<td><em>Kline &amp; Pinch (1996)</em></td>
<td></td>
</tr>
<tr>
<td>Electronic components</td>
<td>NA</td>
</tr>
<tr>
<td><em>Haring (2002)</em></td>
<td></td>
</tr>
<tr>
<td><strong>Consumer Products</strong></td>
<td></td>
</tr>
<tr>
<td>Early US automobiles</td>
<td>NA</td>
</tr>
<tr>
<td><em>Franz (1999)</em></td>
<td></td>
</tr>
<tr>
<td>Hiking equipment</td>
<td>37%</td>
</tr>
<tr>
<td><em>Luthje (2000)</em></td>
<td></td>
</tr>
<tr>
<td>Snowboarding, sailplaning, canyoneering, and handcapped</td>
<td>38%</td>
</tr>
<tr>
<td>cycling equipment</td>
<td></td>
</tr>
<tr>
<td><em>Franke &amp; Shah (2003)</em></td>
<td></td>
</tr>
<tr>
<td>Mountain biking equipment</td>
<td>19%</td>
</tr>
<tr>
<td><em>Luthje, Herstatt and von Hippel (2002)</em></td>
<td></td>
</tr>
</tbody>
</table>
The wide variety of industries in which user-innovation has been documented suggests that it is not ancillary to the innovation process, but a vital component worthy of further study and integration into existing theories of innovation and economic change. To do this we need to understand the process by which a user-innovation becomes a commercialized product. How is information about the innovation transferred to existing or new firms? How do firms decide whether or not to commercialize a user-innovation? The latter question is especially significant because many user-innovations provide novel functionality for which an established market does not yet exist or may never exist (one user’s preferences do not indicate latent or creatable mass-market demand). Thus the question of how and by whom the markets are developed must also be addressed. Insights into this process from several detailed studies are reviewed below; however, the data are limited because the studies were not conducted for the purpose of addressing these questions. Historical work on users and their automobiles by Kline & Pinch and Franz are first discussed, followed by a discussion of von Hippel’s work on innovation by users of industrial goods.

Kline and Pinch examine how rural users not only made technical changes and alterations to the automobile, but also extended its use beyond transportation (Kline and Pinch 1996). Farmers used the engines to run laundry machines, butter churns, water pumps, wood saws, and a variety of other farm equipment: “... although manufacturers may have ascribed a particular meaning to the artifact they were not able to control how that artifact was used once it got into the hands of the users (Kline and Pinch 1996, pg. 775).” News of the innovations traveled far and wide. New kit makers and existing automobile manufacturers responded to the actions of users. Kits offering instructions and components for rigging the automobile for specialized uses were advertised in local newspapers and journals aimed at rural America. The identity of the kit manufacturers is unclear, although it appears that they were not affiliated with the major automobile manufacturers. Automobile manufacturers often learned of the innovations via letters from users, articles in journals, and the increasing number of kits on the market. Most warned against making innovations or using the kits, claiming that the alterations were
likely to damage the engine. Over time, automobile manufacturers developed specialized products for rural users, such as tractors based on automotive design and trucks, and placed formal restrictions on automobile and kit use via warranty provisions and pressure on dealers.

While Kline & Pinch focus on innovations made by rural Americans in the early 1900s, Franz focuses on innovations in automotive accessories made by middle-class American leisure travelers during the same time period. A number of distinct communities, each with its own priorities, may exist around a particular product.

Franz reports that users built and added such features as radiator hoods, safety devices, interior heaters, automobile tops, trunks, reclining seats, and electric ignitions to their cars (Franz 1999). Some even replaced the standard body altogether. Despite their ingenuity, Frantz’s data suggest that the vast majority of user-innovators made little or no money from their activities, although a few managed to license their innovations and a very small fraction started businesses that sold to a local market. “The rewards of tinkering lay not in economic success within the auto accessories market, but in the cultural space of leisure where amateurs produced their own narratives of ingenuity and claimed knowledge of the new machine (Franz 1999, pg. 149).” Many innovators shouldered the cost of disseminating news of their innovations to other automobile enthusiasts. In the early 1900s a high number of journals for automobile enthusiasts - “written by and for devotees of the new “sport” (Franz 1999, pg. 198) - published innovator-written “how-to” articles. Once again, existing manufacturers often learned of the changes via the innovators themselves, through requests for repairs, phone calls suggesting that the manufacturer adopt the innovations, and articles in the hobbyist journals (one of the journals was sponsored by Ford). Despite these avenues for information transfer, substantial time lags existed between the time an innovation was made and communicated to other users, and when manufacturers incorporated it into commercial products. Frantz also points out that the patent record provides a largely incomplete picture of automobile innovation in that time period because many innovating users did not patent their innovations.
Von Hippel’s studies of user-innovation are well-known within the management literature (von Hippel 1988). In the case of scientific instruments, he finds that innovating users (often academic scientists) communicate their ideas to others via publication, symposia, and visits to other users. The longer it took for a commercial product to appear on the market, the more evidence there was of other users building homemade copies of the equipment. In the case of semiconductor and printed circuit board assembly process innovations, von Hippel notes that details of the transfer process between users and producers were not well documented, but it appears that innovating users (most often employees of user firms) shared their information with the staff of other users firms and manufacturer firms. By and large, existing firms were the ones who commercialized user-innovations, although in a few cases users became equipment producers (von Hippel 1988, pg. 24).

1.2.2 Organizational Sociology: Preferences & Industry Structure

Empirical research in organizational sociology points out several ways in which consumption preferences can affect industry structure, although they do not all examine innovation per se and focus on established, not emerging, markets. Three studies highlighting these effects are reviewed below: (1) Peterson & Berger suggest that consumers may withdraw from the market instead of accepting mass-produced products and learning from producers, (2) Carroll & Swaminathan suggest that individual consumers may choose to purchase products from the producers they deem most “authentic”, regardless of quality, and (3) Scott Morton & Podolny suggest that hobbyist producers are likely to produce higher quality products than other producers.

Peterson & Berger study the structure of the music industry and the sorts of music that make it to the “top 10” charts over a 26-year period. Two findings are especially striking. First, they find evidence that consumers whose tastes are not met by “top ten”

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5 Some examples of user-innovation in the field of scientific instruments, just one of the industrial products fields studied by von Hippel and his colleagues, include the electron microscope, well-regulated high voltage power supplies, and the high temperature specimen stage.
records “withdraw from the market,” that is, they no longer purchase “top ten” records, despite repeat presentation and advertising. We do not know if they search for other types of music to purchase or not. Second, they find that changes in market structure precede changes in popular music. This is surprising in light of existing economic theory that predicts that the rate of innovation and change in an industry is a function of market structure\(^6\).

Carroll & Swaminathan build on resource-partitioning theory and propose that issues related to authenticity, identity, and craft lead consumers to choose products produced by specialists, rather than mass producers and contract producers, even when product characteristics across the organizational forms are equal (Carroll and Swaminathan 2000)\(^7\). Their findings are based on a study of the post-prohibition American brewery industry. They suggest that four mechanisms exist to create an appeal for specialist organizations and that different mechanisms may apply to different industries: location, organizational identity, conspicuous status consumption, and “flexibility” (the ability to meet the unique and changing needs of certain customers) over time.

Podolny and Scott Morton study the impact of owner motivation on price and quality in the California wine industry. They find that owners with a “love” for making wine behave differently from owners interested primarily in money. Those with a

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\(^6\) It is possible that while large firms concentrate on producing more of what is currently popular, portions of the population experiment with new styles of music and firms may result as a by-product. The firms grow as interest in the music grows and by the time the music makes it to the “top ten” charts, several such firms are already in existence. Evidence hinting of such a process is presented in the paper: the authors report that “communal” music - music not merchandised through the mass media, but disseminated primarily through live performance – flourished in the 1950s and newly created independent record companies catering to these new styles thrived. At least some new firms appear to have been produced organically, as illustrated by the following example: “Sceptor Records provides a good illustration of the almost causal way in which record companies entered the music field during that period. The company was founded in 1959 by Florence Greenberg of Passaic, New Jersey, to record a four-girl singing group who were her daughter’s classmates. This group, the Shirelles, sold well in the soul market for eight years. They had six top ten popular music hits between 1959 and 1963, securely establishing the company in the popular music market (Peterson and Berger 1975, pg. 164, fn. 3).”

\(^7\) Resource partitioning theory is a branch of organizational ecology that explains the rise of late-stage firms within an industry as an (unexpected) outcome of the consolidation occurring among large generalists organizations as they compete for the largest consumer resource bases of the mass market.
passion for wine production and the associated lifestyle often produce higher quality wines and have a lower profit threshold. The latter makes them more "competitive" than their financially-oriented counterparts. Their study highlights the notion that hobbyists and enthusiasts may take part in economically-oriented activities and that motives other than profit may influence firm decisions.

1.2.3 Community-Based Innovation & Peer Production

The recent rise of open source software development has received considerable attention from academics and practitioners. The notion that a product as complex as software that relies on the talents of highly paid professionals could be produced voluntary and completely outside the boundaries of firms appears extraordinary, yet we can see it occurring. Individuals within some open source software communities are producing robust and popular products that compete with and have, on occasion, displaced commercially produced products. Benkler states "A new model of production has taken root, one that should not be there, at least according to our most widely held beliefs about economic behavior (Benkler 2002)." Benkler provides a substantial and interesting look at the nature of community-based product development in open source software (Benkler 2002).

But is this model really new and limited to the development of software and virtual products? As we saw earlier, users in a wide variety of industrial and consumer product arenas innovate and it is likely that at least some of these users do not work in isolation - the development of ideas into prototypes is likely to require additional resources and assistance. Studies have recently begun to focus on the social context around user-innovation. Users work together as they develop and use their innovations in a variety of industries: amateur radio operators often shared innovation-related information over the airwaves (Haring 2002), sports enthusiasts provide assistance to other sports enthusiasts engaged in making innovative improvements to their equipment (Franke and Shah 2003), Lego robotics enthusiasts congregate on-line (Knudsen 2000), and, as we saw earlier, innovative automobile enthusiasts wrote about their innovations in hobbyist magazines (Kline and Pinch 1996; Franz 1999).
Section 1.3: Method, Setting & Data

The goal of this research project is to better understand how innovations are developed and how user-innovations, in particular, are commercialized. The general context of sports equipment was chosen for two reasons. First, new sports emerge relatively frequently. It is possible to study the economic and social history of new sports via primary data collection methods, including discussions with early innovators and other actors. Second, the fields are largely free of government regulation, a factor that could shift activity towards firms and institutions able to bear legal and financial risk.

An inductive research approach based on the principles of grounded theory building was employed. Grounded theory building is particularly useful in situations where the phenomenon does not fit existing categories or is not readily explained by existing theory (Glaser and Strauss 1967). It is a well-accepted methodology among qualitative researchers in sociology, and is used frequently in strategy and technology and innovation management as well (Eisenhardt 1991; Dougherty 2002). Grounded theory building has three distinct requirements: theoretical sampling, making constant comparisons, and using a coding paradigm to ensure conceptual development (Strauss 1987)

1.3.1 Sports Selected for Study

This study focuses on equipment used in three sports: skateboarding, snowboarding and windsurfing (Table 1-3). These sports were chosen based on two criteria: (1) They were developed relatively recently. Almost all of the innovations for each sport were developed within the last 40 years. (2) They have grown to significant size, each having at least a million participants and equipment sales in the range of $100 million annually by 1998.

Recent development of key innovations allowed for the collection of rich, detailed, and accurate data: information about the histories of the innovations could typically be obtained by interviewing the innovators and others present when the
innovation was being developed or commercialized. Significant market size was important because it meant that both users and manufacturers should, in principle, have an incentive to innovate: users because of the attractiveness of the activity; manufacturers because of the commercial attractiveness of the market. Each sport studied has a group of serious enthusiasts and a contingent of professional racers, as well as mass-market recreational participants.

Several other sports, such as mountain biking and rollerblading, also meet the two criteria just noted\(^8\). We are aware of no bias in our innovation pattern findings resulting from the selection of skateboarding, snowboarding and windsurfing.

\(^8\) The company Rollerblade, a pioneer in in-line skating equipment, does not grant interviews for research purposes; this led to the exclusion of rollerblading from the list.
<table>
<thead>
<tr>
<th>Sport</th>
<th>1998 U.S. Consumer Expenditures (Frequent Participant Data in parentheses)</th>
<th>1998 U.S. Participants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wakeboarding *</td>
<td>&lt; 10 days/year: 1.4 M (1.1 M)</td>
<td>6.5 M participants</td>
</tr>
<tr>
<td>Skiing</td>
<td>(2) 30 days/year: 2.5 M (2.1 M)</td>
<td>5.8 M participants</td>
</tr>
<tr>
<td>Windsurfing</td>
<td>*1.2 M4 M participants</td>
<td>1.24 M units</td>
</tr>
<tr>
<td>(0.31 M) units</td>
<td>&gt; 0.3 M (0.3 M)</td>
<td>$77.0 MM</td>
</tr>
<tr>
<td>(1.5 M) units</td>
<td>&gt; 1.5 M (1.2 M)</td>
<td>$72.5 MM</td>
</tr>
<tr>
<td>Boards, Boats &amp; Accessories</td>
<td>$163.9 M (163.9 M)</td>
<td>10,000 units</td>
</tr>
<tr>
<td>Masts, Masts, Masts</td>
<td></td>
<td>22,000 units</td>
</tr>
<tr>
<td>Booms, Booms, Booms</td>
<td></td>
<td>30,000 units</td>
</tr>
<tr>
<td>Sails, Sails, Sails</td>
<td></td>
<td>29,000 units</td>
</tr>
<tr>
<td>Boards, Boards, Boards</td>
<td></td>
<td>20,000 units</td>
</tr>
</tbody>
</table>

*Frequent estimates in terms of consumer expenditures are for units sold, when available, for each sport have been included.

Source: National Sporting Goods Association (NSGA) or American Windsurfing Industries Association.
1.3.2 Sample Construction

The sample of equipment innovations for each of the three sports was identified as follows. First, individuals who we had reason to believe had some expertise in each sport were contacted. Those contacted included editors of well-known sport-specific magazines, authors of books that discussed the history of each sport, and experts at leading equipment manufacturers. Each of these individuals was asked to identify individuals that he or she judged to have excellent knowledge of the innovation history of each sport. These experts were contacted in turn and asked the same question. Eventually between five and seven experts with very good information on the histories of important equipment innovations in each sport — a few being innovators themselves — were identified. Next, each of these experts was asked to list “the key equipment innovations in the history of the sport.” The lists of innovations independently generated by these experts were then compared. All innovations nominated by three or more experts (not including the innovator if he was also a nominator) were included in the sample.

Via this process a sample consisting of 10 important equipment innovations for snowboarding, 7 for skateboarding, and 40 for windsurfing was identified. The greater number of innovations in windsurfing is likely due to the greater number of parts on a windsurfer: snowboards and skateboards consist primarily of a board; a windsurfer of a board (with a fin and often a dagger board attached), a sail, a mast, and a boom. Each of these parts, as well as the interfaces between parts, can be the object of design work and improvement. All innovations in the sample are listed in the Appendix.

1.3.3 Data Collection

Development and commercialization histories were collected for each innovation identified. Data collection was accomplished primarily through one-on-one telephone interviews with a variety of actors who had insight into the innovation, how it was developed and commercialized, and the state of the industry and market at that time. Whenever possible, the innovator was interviewed to get a better understanding for the
local information employed and the specific circumstances, needs, and problem solving methods surrounding the innovative activity. Interviews with designers, early manufacturers, current manufacturers, magazine editors, book authors, and occasionally professional competitors in the sport were also conducted. Interviews were semi-structured and were designed to collect detailed innovation and commercialization histories for all innovations in the sample. Information used in tables was verified or is in the process of being verified using either a second interview source, published magazine articles, patent applications, old equipment catalogues, or dated photographs, drafts, and sketches.

1.3.4 Key Definitions

Innovator: the firm or individual that first develops a working prototype of an equipment innovation. All individuals are credited for developing an innovation in cases where more than one individual independently developed an innovation and in cases where individuals cited others as “co-innovators.”

The functional locus of innovation is defined in terms of the means used by an innovator to derive benefit from the innovation at the time the innovation was made (von Hippel 1988). Specifically:

User-innovation: An innovation developed by an innovator who, at the time the innovation was developed, benefited only from use.

User-manufacturer innovation: An innovation developed by one or a group of users who benefited both from use and from participation in a small lifestyle firm (10 full time employees or less at the time of innovation) which produced and sold innovative equipment for their sport.

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9 This is a relatively novel approach. Most innovation studies rely on historical documentation and secondary sources.

10 Some qualitative information regarding specifics of the innovation process and where ideas came from is not verifiable.
Manufacturer Innovation: An innovation developed by any type of manufacturing firm (including user-founded lifestyle firms that grew to exceed 10 employees in size at the time of the innovation).

Other: Instances where an innovator does not belong in any of the categories just listed. Example: innovations developed by members of two or more of the categories described above working jointly or by professional athletes are coded as other.

NA: Instances where the developer of an important innovation could not be determined were coded NA (Not Available)

The user-manufacturer category defined above has not been used before in studies of the functional locus of innovation. It is employed here because it accurately characterizes the nature of the benefit obtained by the innovators in the sample who were both (1) early and avid practitioners of their sport, and (2) made and sold equipment to others in order to support their sport-centered lifestyle.

Section 1.4: Findings

Users and user-manufacturers are responsible for 100% of first-of-type innovation and 58% of major improvement innovations in the three sports studied. Details regarding the sources of innovation are presented in this section, followed by data describing characteristics of innovators, their learning and development process, and the methods by which they appropriated benefit from their innovations.

1.4.1 Who Innovates? Patterns in the Sources of Innovation

Sports equipment users developed all of the first of type innovations in each of the three sports studied. Taken together, innovating users and user-manufacturers (user-founded lifestyle firms) developed 58% of all major improvement innovations in the sample. Manufacturers developed 27% of the major improvement innovations and the remaining 15% were developed by other functional sources of innovation (Table 1-4).

On the basis of these data, the hypothesis that existing manufacturers of sporting equipment of any type will be the dominant developers of innovations in these sports is
rejected\textsuperscript{11}. Going one step further, even the conventional wisdom derived hypothesis that manufacturers in general (existing manufacturers, component suppliers, and manufacturers organized to produce specifically for the sport in question) will be the dominant developers of innovations in these sports can also be rejected\textsuperscript{12}.

A more conservative test can be conducted if each innovator rather than each innovation is considered as a statistically independent event. To do this a sub-sample consisting of only the first innovation developed by each innovator is constructed (Table 1-5). Both null hypotheses are still rejected under this constraint, soundly rejecting the conventional wisdom derived hypotheses\textsuperscript{13}.

\textsuperscript{11} A binomial distribution was used to test the null hypothesis that that existing manufacturers of sporting equipment will develop greater than or equal to 90% of the innovations in novel sports (i.e. that probability [innovation by an existing manufacturer of sports equipment] $\geq$ 90%). With 0 of 48 innovations being developed by such manufacturers of sports equipment, this hypothesis is rejected with the probability of type 1 error being less than 1%. Testing a hypothesis in this way requires that each data point be an independent Bernoulli trial. However, because the same innovator or group of innovators often innovated multiple times, this assumption is not readily met. Removing all but one innovation by innovators with two or more innovations in any given sport leaves us with 0 of 22 innovations being developed by such manufacturers. Therefore, the null hypothesis is also rejected under the independence considerations discussed above with the probability of type 1 error being less than 1%.

\textsuperscript{12} A binomial distribution was used to test the null hypothesis that any manufacturer will develop greater than or equal to 90% of the innovations in novel sports. With 12 of 48 innovations being developed by any manufacturer (existing manufacturers, component suppliers, or manufacturers organized to produce specifically for the sport in question), this hypothesis is rejected with the probability of type 1 error being less than 1%. Testing a hypothesis in this way requires that each data point be an independent Bernoulli trial. However, because the same innovator or group of innovators often innovated multiple times, this assumption is not readily met. Removing all but one innovation by innovators with two or more innovations in any given sport leaves us with 7 of 22 innovations being developed by such manufacturers. Therefore, the null hypothesis is also rejected under the independence considerations discussed above with the probability of type 1 error being less than 1%.

\textsuperscript{13} The results of all the hypotheses tested are also valid if we conservatively assume that manufacturers in general will develop greater than or equal to only 75% of the innovations in novel sports. If we go so far as to assume that manufacturers in general will develop greater than or equal to only 50% of the innovations in novel sports, the first hypothesis is upheld with the probability of type 1 error being less than 1%, but the second is not; however, the second hypotheses can be rejected at the 7% level.
<table>
<thead>
<tr>
<th>Sport</th>
<th>Innovation Type</th>
<th>Developed by Users and User-Mfrs</th>
<th>Number of Innovations Developed by:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>100%</td>
<td>User</td>
<td>User-Mfr</td>
</tr>
<tr>
<td>Skateboarding</td>
<td>First of Type</td>
<td>100%</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Major Improvement</td>
<td>67%</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Snowboarding</td>
<td>First of Type</td>
<td>100%</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Major Improvement</td>
<td>67%</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Windsurfing</td>
<td>First of Type</td>
<td>100%</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Major Improvement</td>
<td>53%</td>
<td>3</td>
<td>13&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td>9</td>
<td>13&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

Percent of First of Type<sup>c</sup> 100%
Percent of Major Improvement<sup>c</sup> 58%

(a) 13 of these are attributed to the firm Windsurfing Hawaii.
(b) 2 of these are partially attributable to the firm Windsurfing Hawaii.
(c) Innovations for which the developer is unknown have been excluded from percentage calculations.
TABLE 1.5: FUNCTIONAL SOURCE OF INNOVATION - FIRST INNOVATION BY EACH INNOVATOR ONLY

<table>
<thead>
<tr>
<th>Type of Innovation</th>
<th>Number of Innovations Developed by:</th>
<th>Developed by Users</th>
<th>User Hits</th>
<th>User-MFR Hits</th>
<th>MFR Hits</th>
<th>Other Hits</th>
<th>MFR-MFR Hits</th>
<th>Unknown</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sport</td>
<td>Total</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
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</tbody>
</table>

(a) Innovations for which the developer is unknown have been excluded from percentage calculations.
Sources of First of Type Innovations

In all three of the sports studied, users developed the initial first-of-type innovation. Skateboarding began in the early 1900s, when children played and rode on wooden scooters, often homemade, consisting of a board with roller skate wheels and a handle attached for control. Over the next five decades, adventurous users removed or did without the handle (it often broke off), thereby creating the first skateboards. In the case of snowboards, children have slid down hills standing up on various vehicles ranging from sleds to garbage pail lids and cafeteria trays for ages\textsuperscript{14}. Sometimes, as in the case of sleds or toboggans, a rope was attached to the front of the vehicle to pull it up hills. The rope also functioned as an aid to balancing while riding while standing up. In the case of windsurfing, the innovation was specific to an individual user, Newman Darby. Darby was the first to put a universal joint at the base of a mast on a floating platform (1964), so that the user could directly manage the direction of sail by standing up and holding the boom and tipping the mast (Darby 1997)\textsuperscript{15}.

Sources of Major Improvement Innovations

As was noted earlier, users and user-manufacturers developed 58% of all improvement innovations. These categories are joined together, because the firms in the user-manufacturer category were lifestyle firms, typically started after its founders had

\textsuperscript{14} "The truth is, no one person did it. People have been trying to stand up on their sleds forever, or at least as long as they have been sleds (Howe 1998, pg. 6)." Experts agree that the "formal" history of the snowboard begins with Sherman Poppen's Snurfer (section 4.3), although there is evidence of other activity in the field. For example, there are accounts of WWI soldiers standing sideways on barrel staves and sliding down snowswept hills while stationed in Europe and the recent discovery of a video dating back to 1939 shows a man named Vern Wicklund riding a snowboard-type sled sideways down a small Chicago hill (Wicklund family members have uncovered patents for the board, which had footstraps, nose cords, and a turned-up nose) (Burton 2003).

\textsuperscript{15} Newman S. Darby, a Pennsylvania sailboat enthusiast who had been building boats as a hobby for over a decade and a commercial artist by trade, built a functioning prototype of a sailboard in 1964. In 1965 he published his design in Popular Science (August). He and his brother then set up a small facility in Western Pennsylvania to build and sell sailboards. They sold approximately 80 of these sailboards during 1965-1966 and gave several away on the television program The Price is Right. The Smithsonian Institution considers Newman Darby to be the "true founder" of windsurfing. All the key elements of a windsurfer were present in Darby's design. However, many experts in the windsurfing industry today credit Jim Drake for designing the windsurfer "as we know it" and credit Hoyle and Diane Schweitzer for actively marketing the sport and being the first to organize the manufacture of windsurfers on a relatively large scale. Drake was familiar with Darby's work and first sailed his design in Marina del Ray, California on May 23, 1967 (Drake 1996).
prototyped and begun to refine an innovation\textsuperscript{16}. By lifestyle firm, we mean a firm with ten or fewer employees that is used to "hold body and soul together" for innovating users while they continue to innovate and advance their skills in their sport. At the time important innovations were being made by user-manufacturers, these firms were run out of a garage, small storefront, or spare room; had no capital equipment beyond portable power tools; and produced products one by one (occasionally in small lots). The innovators typically worked full time at other jobs. These were private individuals who were innovating and producing prototypes on a small scale, not companies focused primarily on mass production.

A description of innovation activities among “the Hawaiians” conveys the flavor of innovation, fun, and competition intermixed with small-scale production that characterized user-manufacturers. The Hawaiians were a group of 4-7 people in their early 20s who lived together in a house in Kailua, Hawaii\textsuperscript{17}. They windsurfed daily off a beach near their house. As they experienced the very high wind and wave conditions common to the area and experimented with various new windsurfing techniques and tricks, new needs emerged – needs that the existing equipment could not fulfill. They innovated in order to tailor the equipment to the conditions they were experiencing and the techniques they were developing. As people who saw or heard about their advanced sailing techniques and equipment asked to purchase the equipment, they made and sold handmade copies of their innovative equipment from their house (for the first 3 or 4 years) and then from a small storefront.

\textit{Manufacturers} developed 27% of the major improvement innovations in the sample. Seventy-five percent of these innovations (n=9) were developed by existing sports equipment

\textsuperscript{16} Small, local producers – often kids making copies of equipment in their parents’ garages or older enthusiasts working in their own homes - also existed in all three sports. The founders of these firms were often also hobbyists, but here we restrict our attention to firms started by user-innovators.

\textsuperscript{17} "The Hawaiians" were a group of active windsurfers in Kailua, Hawaii on the island of Oahu in the 1970s; the group includes Mike Horgan, Larry Stanley, Ken Kleid, Pat Love, and Andy Chaffee. Dennis Davidson and Colin Perry were members as well, but they did not live with the group; they lived nearby and were daily contacts, both at the house and at the windsurfing sites. Members of this group were responsible for many innovations in high performance windsurfing and built and sold prototypes out of their garage for several years (approx. 1974-1978). In March 1978 several of them jointly founded the firm Windsurfing Hawaii Inc. and moved the operation to a storefront in Kailua.
component suppliers. These innovations involved transferring specific technology and know-how from an existing sport to the novel one. For example, a maker of fins for surfboards was asked to design a fin that would solve some windsurfer-specific problems. Similarly, a producer of shoe-bindings for bicycles (used to connect bicycle pedals firmly to bicycle riders' shoes) adapted their technology to attach snowboarders' boots firmly to snowboards. In all but one case, the manufacturers who developed these innovations were small craft shops run by their founder-owners – large firms with product development generally did not develop these innovations. The remaining 25% (n = 3) of manufacturer innovations in the sample were made by manufacturers organized specifically to produce for the sport in question. Two of these innovations were developed by employees of Burton Snowboards after it grew beyond the 10-employee level and moved from the category of user-manufacturer to manufacturer according to the coding criteria described earlier (section 1.2.4).

Although existing toy and sports equipment companies were not significant innovators in the new sports we studied, some such companies did play a significant role in aiding the diffusion of the sport. After market take-off, some existing toy and sports equipment companies began producing copies of the equipment developed by the innovators. Sometimes they refined the equipment in minor ways; more often they simply cheapened it to lower the price for mass-market consumers. These manufacturers also contributed to the diffusion of each sport by engaging in major promotional and marketing efforts.

1.4.2 Who are These Innovative Users and User-Manufacturers?

Most of the user- and user-manufacturer-innovators whose innovations we studied were early and extremely enthusiastic participants in their sport and their innovations often led the emergence of the mass-market by a number of years (Figure 1-2) 18. Interview data indicate that they were passionate users of the sporting equipment and

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18 They can be characterized as lead users (von Hippel 1986). Lead users are defined as users who exhibit both of the following two characteristics: they have a high need for an innovation and they experience that need ahead of the bulk of the target market.
were eagerly seeking and developing new techniques that required related innovations in equipment.

“Our model was we build it for ourselves. I didn’t want this stuff to break when I was out sailing in 15-foot waves or from Molokai to Oahu when you can’t see land in either direction... Built to last and the people who used our stuff understood.”

Many of these same individuals were also responsible for other types of important innovations not included in the sample. For example, some introduced new riding tricks and techniques, and, in the case of skateboarding, developed early skateboard parks and various types of skateboarding ramps such as half-pipes. They are in some ways the sports equivalent of software hackers, always trying to test and push the limits of their sport via innovations in technique and equipment. Some engaged in promotional activities that also resulted in the growth and development of the sport.

Innovating users in the sample were generally young sports enthusiasts who had typically chosen to pursue their sport and the associated lifestyle. Many either did not attend college or attended for only 2-3 years. Only a few had college degrees and only three user-innovators are known to have received formal engineering training\(^\text{19}\)\(^\text{20}\). Most had carpentry or basic woodworking skills and often described themselves and those who assisted them as self-taught or "seat-of-the-pants" engineers. Many learned these skills as a normal part of growing up - in the boy scouts, woodshop, or garage. Several learned woodworking and mechanical arts skills on military bases as children or as adults.

\(^{19}\) Newman Darby, inventor of the windsurfer, commented at the Smithsonian in April 1999 that, “You have to keep trying...You don’t have to have a college degree to be an inventor. Kids invent things in their bedrooms.”

\(^{20}\) Sherman Poppen, innovator of the Snurfer, was a chemical gases engineers in Muskegon, Michigan with several industrial gas patents to his name. Jim Drake, of windsurfing fame, spent much of his career as an aerospace engineer with the Rand Corporation. Dimitrije Milovich, founder of Winterstick and responsible for several snowboarding and windsurfing innovations, has an engineering degree from Cornell. Both Drake and Milovich are known to have been active sports enthusiasts.
"I'd say we were generalists. I was probably the best [chuckle] carpenter in the group. The others had some skills in carpentry that they developed over the years, but we were all pretty much generalists. We all came from backgrounds where we had motorcycles or cars or you know model airplanes or whatever so we were good at making pieces that fit and shaving them down to make them fit and adapting this piece of wire and that pieces of plastic to make this part that we needed that we couldn't buy. We were all more like that."
FIGURE 1-2: INNOVATIONS AND MARKET GROWTH OVER TIME \(^{21,22}\)

\[\text{Time (relative to initial consumer market growth)}\]

\[\text{# of Innovations} \quad 21+ \text{years prior} \quad 11-15 \text{years prior} \quad 1-5 \text{years prior} \quad 6-10 \text{years post} \quad 16-20 \text{years post} \quad 26-30 \text{years post}\]

\[\text{Approx. Number of Users} \quad 0 \quad 10 \quad 100 \quad 1,000 \quad 10,000 \quad 100,000 \quad 1,000,000\]

\[^{21}\text{According to industry experts, mass consumer market participation in “standard” windsurfing begins in 1973; in high performance windsurfing in 1981; in snowboarding in 1986; and in skateboarding in 1963.}\]

\[^{22}\text{Data based on interviews with expert manufacturers and users active in the field at the time. Published market data estimates do not appear to be available for the early phases of these markets.}\]
1.4.3 User Learning & Product Development Processes

The learning process engaged in by the user and user-manufacturer innovators was very much a learning-by-using process involving repeated trial-and-error and assistance from others. Participants were competitive with each other in a collegial way and generally willing to share their equipment and what they had learned with others who were serious about the sport. Consider the following example — the development of footstraps for windsurfing:

Mike Horgan and Larry Stanley (members of Windsurfing Hawaii) were jumping with their windsurfing boards in 1974 and 1975. The problem was that the riders flew off in mid-air because there was no way to keep the board with them. As a result, they hurt their feet and legs, and damaged the board. They soon lost interest in jumping and moved on to other things. In 1978 Jurgen Honscheid came over from West Germany for the first Hawaiian World Cup and discovered jumping. A new enthusiasm for jumping arose and soon a group of windsurfers were all trying to outdo each other. Then Larry Stanley remembered the Chip (a small experimental board he had built a few years prior) with its footstraps and thought:

"It's dumb not to use this for jumping... And that's when we started jumping first with footstraps and discovering controlled flight... I could go so much faster than I ever thought and when you hit a wave it was like a motorcycle rider hitting a ramp — you just flew into the air. We had been doing that but had been falling off in mid-air because you couldn't keep the board under you. All of a sudden not only could you fly into the air but you could land the thing and not only that but you could change direction in the air! The whole sport of high performance windsurfing really started from that. As soon as I did it, there were about 10 of us who sailed all the time together and within one or two days there were various boards out there that had footstraps of various kinds on them and we were all going fast and jumping waves and stuff. It just kind of snowballed from there."
Most of those who made key innovations worked with others as they developed and refined their prototypes. Consider the following description of working jointly:

"...we were all helping each other and giving each other ideas, and we'd brainstorm and go out and do this and the next day the guy would do it a little better, you know, that's how all these things came about."

Ideas and prototypes were shared with those who gave assistance, the local community, and with any and all interested enthusiasts. Many “how-to” articles related to equipment and technique were written by the user-innovators and published in magazines, e.g. Newman Darby published designs for his windsurfer in Popular Science magazine; the Hawaiians published designs for their innovations in popular windsurfing newsletters and magazines and openly spoke about them with visitors to Hawaii and competitors and enthusiasts at windsurfing competitions; and one snowboarding innovator made it known that he would not enforce his patents against users or other firms in the industry.

In interviews, two primary reasons were cited for this behavior: fun and enjoyment and a desire to build the field:

Fun and Enjoyment: "If you did not share... [others] would not be able to keep up with you. To do or experience something new and fantastic or go another step faster isn't much fun when you shout 'Wow! Did you see that!' and nobody is there to hear you."

Building the Field: "We knew that we were just scratching the surface... The more we worked together, the sooner we'd go faster or do new things."

For these innovators, the sport was a source of enjoyment and pleasure. It was a hobby.
Two exceptions to this sharing behavior were observed. First, there was a slight lag when racing or competing:

"Some of the equipment and techniques specifically related to racing were given out as well. The timing was just a little different in those cases... after the race, not before."

Second, across all three sports, only developments and refinements made to windsurfing sails were hidden.  

1.4.4 Patterns in the Appropriation of Innovation-Related Benefits

Innovators may capture benefit from their innovations in a number of ways. First, and most directly, if they are users they may benefit from personal use of their innovation as they practice their sport. Less directly, anyone or any firm, whether user, manufacturer or other, may benefit from the reputation increase associated with having developed an important innovation. However, if innovators wish to capture monetary profits from their innovation, they must somehow first protect it via intellectual property law and license that protection to others. Alternatively, they must produce the innovative equipment for sale to others and obtain innovation-related rents during the time period when they still have an advantage over would-be imitators.

Manufacturers who patented innovations generally did not license them to others – they benefited from their patented innovations by producing and selling them. Non-manufacturers in the sports fields studied sometimes patented their innovations (Table 1-6), but did not find this patenting and licensing a very successful route to capturing innovation-related benefits. To our knowledge, there is only one case in which a patent

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23 There are several possible reasons for this. The most instrumental is that they could be hidden, because changes to sail shape and design are particularly difficult for an untrained eye to notice. More likely, the reason lies in the fact that while most of the innovators had basic mechanical skills, very few knew how to sew. In the case of the Hawaiians, only one member of their group knew how to sew and they often had friends who were sailmakers (for boats) design and make their sails. Thus they may not have been able to tell others about sail design and construction because they had limited information regarding
was successfully licensed by an innovator to a manufacturing firm for the life of the patent and one case where a patent was sold. In a third case, licensing fees were briefly obtained, but then the patent in question was overturned in court on the grounds that the innovation was not novel enough to have deserved a patent. In a fourth case, the innovator received royalty payments for a few years while maintaining a close consulting relationship to the manufacturer, but the payments stopped when the manufacturer's management changed and the consulting relationship ended, despite subsequent legal intervention.

There are a number of possible reasons for the low level of patenting observed. Innovators may not have been interested in patents and licensing, because they did not realize the commercial possibilities of the innovation; because they could not afford the costs of obtaining a patent; because the technical novelty of the innovation did not rise to the level of being recognized as a patentable innovation\textsuperscript{24}; because immediate public use of their innovations made patenting legally impossible\textsuperscript{25}. Innovators in this field also did not have the ability to protect their innovations as trade secrets, because innovations are openly displayed during use.

Of all the expert practitioners who innovated, 71\% sought to profit from their innovations by forming small, lifestyle firms that would produce their innovations for sale to others (Table 1-7). This was by far the most frequent mode of obtaining financial benefit used by the innovators in the sample.

\textsuperscript{24} However, the US patent record contains many patents for snowboards, skateboards, windsurfers and related equipment.

\textsuperscript{25} United States patent law states that an innovator has one year from the date an "enabling disclosure" is made to file a patent application. An enabling disclosure is one that enables an expert in the same field to use the innovation. An offer for sale is equivalent to an enabling public disclosure in the United States. Patent law in other countries is not so lenient and, in virtually every developed country other than the United States, dictates that an innovator may not apply for a patent after an enabling disclosure has been made.
<table>
<thead>
<tr>
<th>Sport</th>
<th>Non Manufacturer Innovations$^1$</th>
<th>Patented Innovations$^2$</th>
<th>Licensed Innovations$^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number</td>
<td>Percent</td>
<td>Number</td>
</tr>
<tr>
<td>Skateboarding</td>
<td>5</td>
<td>1</td>
<td>20%</td>
</tr>
<tr>
<td>Snowboarding</td>
<td>7</td>
<td>1</td>
<td>14%</td>
</tr>
<tr>
<td>Windsurfing</td>
<td>24</td>
<td>6</td>
<td>25%</td>
</tr>
</tbody>
</table>

$^1$ Excludes the nine windsurfing innovations for which the innovator is unknown.

$^2$ Percentages based on the number of non-manufacturer innovations in the entire sample (column 2).
<table>
<thead>
<tr>
<th></th>
<th>36</th>
<th>22 (71%)</th>
<th>10 (29%)</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>14</td>
<td>0</td>
<td>14</td>
<td>0</td>
<td>User-Manufacturer</td>
</tr>
<tr>
<td>10</td>
<td>2</td>
<td>2</td>
<td>6</td>
<td>Users &amp; Other</td>
</tr>
<tr>
<td>4</td>
<td>0</td>
<td>4</td>
<td>0</td>
<td>User-Manufacturer</td>
</tr>
<tr>
<td>3</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>Users &amp; Other</td>
</tr>
<tr>
<td>4</td>
<td>0</td>
<td>4</td>
<td>0</td>
<td>User-Manufacturer</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>Users &amp; Other</td>
</tr>
</tbody>
</table>

**Explanation of Coding Categories:**

- **Consulting Fees - Innovators:** Fees paid to consulting firms by innovators.
- **Licensing Fees - Innovators:** Fees paid by licensees to innovators.
- **Royalties from Own Manufacturing:** Royalties generated from the sale and production of their own innovations.
- **No Benefit:** Innovators received no financial benefits from their innovations.
- **Users - Other:** Users other than manufacturers.
- **Unknown:** Innovators who were not in a consulting category.

**Method of which Financial Benefits Appropriated:**

<table>
<thead>
<tr>
<th>Sport</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-Manufacturers Appropriated</td>
<td>Licensure or Sales Fees</td>
</tr>
<tr>
<td>No Benefit or Consulting Firm</td>
<td>From Own Manufacturing</td>
</tr>
<tr>
<td></td>
<td>From Licensing Firm</td>
</tr>
</tbody>
</table>

**Table 1-7:**
Section 1.5: Discussion

We have seen that expert practitioners of three sports, primarily young men in their twenties, developed most of the innovations in their respective fields. We have also seen that many of these innovators freely shared information about their innovations and founded lifestyle companies to manufacture their innovations for sale. These findings are discussed in light of innovation and design theory.

1.5.1 Why Was Innovation Concentrated Among Users?

Recall first that we have found that most of the important equipment innovations developed in snowboarding, skateboarding and windsurfing were developed by early and dedicated practitioners of the sport. At the time they developed their innovations, these practitioners were either individual users or founders of a lifestyle firm intended to produce copies of existing equipment for sale. In sharp contrast, we have seen that existing sports equipment firms – even those producing products closely related to snowboarding, skateboarding and windsurfing were not present as innovators in these new fields.

This finding is certainly contrary to conventional wisdom. There is a vast marketing and product development literature devoted to helping manufacturers better understand consumer needs. This literature generally assumes that it is the manufacturer’s role to understand and identify market needs, engage in research and development as well as prototyping activities, and then commercialize and diffuse the resultant innovation.

It is useful to consider why the innovation pattern observed is so at odds with this conventional wisdom. The pattern can be better understood in terms of both the relative expectations of innovation related benefits held by users and manufacturers and the allocation of information between users and manufacturers.
Expectations of Benefits

With respect to the first issue, it has been shown that expectations of innovation-related benefit held by would-be innovators is positively associated with the likelihood they will innovate (Mansfield 1968; von Hippel 1988). In consumer goods fields, one might assume that this type of calculation would predict a pattern of innovation by manufacturers. After all, each of the fields studied has grown to have millions of practitioners of the sport who purchase equipment. Yet, we see that innovation in the fields studied often comes from individual users.

A possible explanation of this puzzle is suggested in the model developed by Stern and Gans (Stern and Gans 1998). In essence, this model argues that innovations by users make sense when the market for products or services is very small and when the ultimate size of the market is very much in doubt. Under these conditions, users get significant personal benefits from practicing their sport; benefits that can be sufficient to drive innovation. In contrast, existing manufactures observe a very small marketplace with an uncertain appeal to future mainstream users and decide that there is not sufficient incentive to induce them to innovate.

The conditions just described do appear to apply to the early days of the fields studied. During the time the innovations were being made by users, knowledge of skateboarding, snowboarding and windsurfing was not widespread, and the market for innovative equipment in these fields was indeed very small. The lifestyle firms established by innovating users who sold handmade copies of their equipment to their friends may have been tapping much of the market for innovative equipment that existed at the time. Gans & Stern's line of reasoning provides a potential explanation for why existing manufactures might not have innovated (even if they could – a highly suspect assumption), however, there is a bigger puzzle at hand. The two conditions encompass innovation in many emerging or small industries as well as innovations with uncertain market potential, yet many innovations made under these conditions are later produced by mass-producers and consumed by the mass-market26. We need to explain how small
and uncertain markets for such innovations grow (it would appear that existing manufacturers are not doing the "teaching" in these cases) and how the mass-market comes to embrace some user-innovations.

**Information Regarding the Use Context: Sticky & Emergent**

Information and access to use conditions also favored discovery and innovation by users over manufacturers. Users had made and continued to make very heavy time investments in the technique of the sport. These investments were necessary to get them to the level of skill needed to engage in learning-by-doing at the outer edges of what was known to be possible in their sport. Also, it allowed them to test solutions under field conditions in ways that could not be done by less experienced users or employees of manufacturing firms. Learning-by-doing was the only feasible method of innovation and test since information about the use context was both "sticky," meaning that it could not be easily modeled or transferred between the user and manufacturer (von Hippel 1994), and still emerging (Alexander 1964; Clark 1985).

Manufacturers who wished to innovate would have had to invest to acquire sticky and emergent use-related information. In principle, they could do this by hiring expert users to work in their product development activities and/or they could invest in enabling some of their existing R&D personnel to become very proficient in the new sports. Neither possibility, however, would be easy to accomplish. The former is likely to be difficult because the ex ante identification of these individuals is difficult, if not impossible\(^ {27} \). It might also be culturally difficult for most established firms to work with user innovators. For example, in the sports studied many users-innovators were relatively young and often had little college or technical education. With respect to the latter, it would be very difficult for manufacturer development personnel to become accomplished in the sport at the level of many of these users requires significant investments of time, and physical and mental energy. A partial "solution" would be to hire users already known as innovators as consultants and/or to hire teams of gifted sports practitioners who

\(^{26}\) A characterization that would appear to include everything that offers novel functionality.

\(^{27}\) Recall that the patent record documents many sports equipment innovations made by users.
would tour the country to demonstrate the sport – and who could also test any new equipment models developed by the manufacturer. Some manufacturers did just that. Interviews with a few team-riders suggest manufacturers rarely asked for or acknowledged their design advice and used them almost solely for marketing purposes.

1.5.2 Why Did User-Innovators Found Firms?

The next element to be explored in more detail is the choice of many innovating expert practitioners to form small firms to exploit their innovations. Other studies of innovations by individual users documented a few cases of such behavior (von Hippel 1988, pg. 24; Franz 1999), but the pattern is not as strong as it is here. Why? Two of the factors that may influence a user-innovators decision - opportunity costs and modularity in product design - are discussed below.

It is reasonable that innovating users would adopt the role of manufacturer if that role promised greater innovation-related profit after switching (start-up) costs had been factored in. The ability to capture innovation-related benefit will only differ among functional roles if innovators cannot license their innovation effectively and at low cost (if effective and low-cost licensing were possible, innovators could license to someone already occupying the favored role, and avoid the switching costs involved in adopting a new role themselves).

In the fields studied, manufacturing innovative equipment offers an opportunity for greater monetary gain than does simple personal use by an innovator (also, an innovating user does not lose the opportunity to benefit from use by adding on the role of manufacturer – he simply gains a pathway to additional benefit). Analysis of patenting and licensing patterns makes it appear that effective and low-cost licensing is not possible in this field (only 17% of the non-manufacturer innovations in our sample were patented, and only one was successfully licensed)²⁸.

²⁸ Engineers and scientists may have more leverage in obtaining and enforcing patents and also have contacts within manufacturing firms that might be useful in establishing licensee relationships. It is also possible that courts are more likely to respect their patents since the patent holders have considerable
Taken together, these two conditions suggest that innovating users would have an incentive to adopt the role of manufacturer if this could be accomplished at a cost commensurate with the expected benefit.

In this field, the cost to a user of adding on the role of a small scale producer relying on relatively low-tech, low-cost, and easily accessible methods of production was often very low. Innovating users were already building prototypes for their own use. Adding on the role of manufacturer simply required making additional copies of the equipment using methods and tools they already possessed (acquisition of expensive capital equipment, such as production tooling required to produce plastic parts in volume, was never done by these firms during their early stages). Advertising was initially done via word-of-mouth and was often a direct and relatively costless consequence of community participation.\textsuperscript{29}

Given the low cost associated with manufacturing on a small scale, it is reasonable that innovating users would tend to adopt the role of manufacturer as well. They might be characterized as being equivalent to “ski bums” who move from ski resort to ski resort, taking ski instructor jobs or lower-wage jobs in order to have constant access to good skiing opportunities. Since the sports of our innovating users were new, there was no commercial infrastructure in place that could offer expert practitioners the equivalent of “ski bum” jobs in skateboarding, snowboarding, or windsurfing. One alternative that existed was to shift their own activities from making prototypes only for themselves to making handmade equipment for others using the similar simple tools and techniques\textsuperscript{30}. Even small returns from this enterprise would be enough to support a sport-centered lifestyle at the beach, on the streets, or in the mountains. As we saw from our

\begin{footnotesize}

\textsuperscript{29} Increased demand later led some of these firms to outsource production or invest in capital equipment. Over time, such firms also began advertising more formally.

\textsuperscript{30} Interview data suggests that some of these individuals saw the market potential for their devices, most if not all of these innovators were approached at some time by other sports enthusiasts who saw their equipment and desired that equipment for themselves.

\end{footnotesize}
data, this alternative was indeed seen as attractive and taken up by a number of innovating users.

In other industries where this matter has been studied, innovators who wished to add on or switch to a different role with respect to an innovation (for example, from user to manufacturer) generally had to incur more significant costs to do so and often also had more attractive alternative investment opportunities as compared to the innovators in this sample. Imagine a scientist who has developed an innovative instrument and is considering adding on the role of instrument manufacturer to her activities. The scientist would find the need to make significant new investments in assets and knowledge specific to that new activity. Similarly, a user firm that has developed a new process machine would face the need to make a similar series of new investments in order to enter the new business of process equipment production and sale. A great deal of work and effort would be required in order for the user or firm to appropriate benefit from the innovation through manufacturing. Both the scientist and the user firm might find that competing opportunities to invest in the existing business might yield more attractive and less risky returns and therefore be reluctant to add on or switch to the role of manufacturer (and in addition, they might be able to appropriate benefit through some form of intellectual property protection). Within this sample, we see a windsurfing innovator who was also an aeronautical engineer chose not to switch roles:

“For my part, I had an entirely separate and successful career and felt little motivation once the concept proved both sound and fun. I felt then and feel now a lot like the father of a talented child that I treated with benign neglect.”

- Jim Drake (Drake 1996)

Product design factors will also play a role in determining whether users form companies. Modularity in product design makes it easier for user-innovators to start firms, because they can produce an equipment component or “kit” to be used in
conjunction with equipment produced by existing manufacturers. The user needs to make investments specific to that particular component only. Competing manufacturers have historically responded to kits in a variety of ways, including incorporating the features into their own products, putting contractual obligations on retailers to not sell or install kits, adding warranty provisions that do not allow kit use, closing or complicating the product design structure to prevent "tinkering" and innovation by users, and discrediting the expertise of user-innovators, while promoting themselves as the instigators of product change and economic growth (Kline and Pinch 1996; Franz 1999). In contrast, if the product is not modular, the user innovator might have to produce the entire piece of equipment rather than just a component part. Making significant new investments in assets specific to that new activity (e.g. knowledge of other parts of the equipment, machinery, licenses for use of patents held by others) may not make economic sense, leading to free-sharing of information about the innovation which may ultimately be picked up and commercialized by existing manufacturers.

1.5.3 The Role of Communities

How did these individuals progress from innovating users to firm organizers? How did they "know" that their innovation was a viable market concept? This paper proposes the idea that "communities" are critical to innovation, firm, and market development. Discussions with many user innovators indicates that positive feedback and requests for the equipment from others - who had heard of the equipment from other enthusiasts or in newsletters and magazines - led many user-innovators to make handmade copies of the equipment for free or at-cost. Eventually, they realized that they could sell the equipment and make some profit.

"We were selling this stuff for four or five years just through ads and mostly word of mouth. Again it was a small community and initially everyone knew where to get this stuff. We didn't need a catalogue cause we were the only ones selling this stuff. And later when we did a catalogue, we were in competition with several other companies... and the
development of a lot of these things was 4 years in the past... I do have the first catalogue - it was all drawings, cartoonish.

We got into the business because we couldn't get anybody to build stuff for us the way we wanted and when we told them what we wanted, they would say "Impossible, it would cost way too much." ... We knew that people would buy this stuff no matter what it cost if it worked and it was the only thing that worked. So, we built it ourselves and it was expensive and we sold lots of them.

We are not and were not the only innovators. Many people were passionate about the sport. There were people who'd live out of their vans for 6 months to a year... There were enough people doing that so that the innovation continued. Still is, always has been stuff out there that's really good.

Communities provide several innovation related benefits. First, community members might work with innovators and provide innovation-related ideas and assistance. Second, communities may serve as an effective selection mechanism since rich information (e.g. reactions of other enthusiasts, perceived urgency of their need) can be fed back to innovators and used for screening ideas. Third, markets may be created or built via a community through word of mouth, newsletters, and observation. Communities are likely to be especially important when an innovation addresses novel set of use conditions or preferences.

There are many reasons why an individual might share his or her innovation with others. Remember however that most of these innovators thoroughly enjoyed their sports and often practiced the sport with others; much of the "reward" lay in future improvements and continued use. It makes sense to reveal the innovation (unless the innovator believes the design is ideal), since revealing opens the door to getting feedback and improvements ideas from others. From this perspective, one of the worst outcomes
would be for a manufacturer to appropriate the innovation and prevent further improvements and/or production by others. Public exhibition and documentation of the innovation may help prevent this, as might patenting an innovation and then allowing others to use it freely. Many questions surrounding the issue of why user-innovators share their work and if and how they protect their work remain to be resolved. Several authors have made contributions in these areas (Kollock 1999; Harhoff, Henkel et al. 2000; Franke and Shah 2003; O'Mahoney 2003).

Many user founded firms became well-known and respected within their industries as makers of exceptionally high-quality equipment. Several still exist and the brands established by others have been purchased by larger manufacturers. Enthusiasm for the field significantly affected the behavior of user founded firms. The differences in perspective and resources (manufacturing equipment and expertise, financing) between these firms and firms interested in mass manufacturing is clearly illustrated in the following quotes in which user-manufacturers recount the experience of outsourcing production to large manufacturing firms (who often produced under their own brand names and sold extra manufacturing capacity to smaller firms):

"They were always making assumptions – I guess they felt that we made things the way we did because we were only using materials we had at hand and adapting the materials and weren’t really thinking it through to find the most efficient inexpensive way to do it. The fact was that we weren’t stupid and we had figured these things out and we had tried to use other materials because we thought hey it’s nice to make it as inexpensive as possible, but in our experiences, the materials didn’t work and that’s why we used better materials – you get what you pay for.

You went to a big manufacturer and told them, we’re selling more of these things that we can make at a premium price and using the best materials and paying attention to detail and we want to keep doing. They absolutely could not understand that. They have finally learned that, but after 10-15
years. For those years the stuff coming out of Hong Kong, China, and even Europe was atrocious. That's why we thrived! Our model was we build it for ourselves.... That was our reputation until it got to the point where we absolutely had to go to outside manufacturers and they just didn't pay attention. That was another part of the reason we suffered in the later years... Finally, it got to point that we said build it this way or we're going somewhere else. They would charge us as much they had to, we'd mark it up as much as we'd have to and we were happy.... Other companies then jumped on the idea, saying we could build that for $15 and we're charging $20. Next thing we knew, we were the only ones charging $20 and there were 10 companies charging 15. It was all crap and didn't last half as long as ours did. But people saw that there were 4-5 types selling for $15 and saw ours at $20... So little by little, we would had to drop out since we weren't going to compromise on design or materials and we couldn't make it any cheaper because our quantities weren't in the millions. They were in the thousands. We couldn't go against [list of big manufacturers] and guys that owned their own factories. [Names of 2 companies] were building stuff for their own line and for us – guess whose was cheaper? Sometimes the same stuff [that we had innovated and designed]! You could buy it for 30% less than our stuff.”

Section 1.6: Process Model & Implications of Community-Based User-Innovation

In this section, a process model of the innovation and commercialization process that includes user innovators and communities is developed (Figure 1-3) and its implications are explored. This model supplements the standard model discussed earlier in this paper (Figure 1-1).

A user may encounter a new want or use environment requiring equipment or services different from what she currently possesses. The user may search for existing solutions, request a solution from a manufacturer, work around the problem, or ignore the
need altogether. A few users may innovate alone or with the assistance of others in response to the perceived design deficiency. Some users keep the innovations to themselves, while others share their innovations. The latter is likely to occur in cases where the user thinks the innovation is very particular to his or her needs or wishes to keep the information proprietary. Employees of user firms in competitive fields or professional athletes may also fall into the latter category. Even in these cases, news of the innovation may spread to others via observation or movement of employees. When users do share innovations with others, news of useful innovations is likely to spread (Rogers 1983) and further improvements, alterations, and refinements are likely to be made by other users. This network of loosely affiliated individuals who share a common interest is a community. Individuals within the community, including the user-innovator, may observe interest in the innovation and choose to promote and commercialize it. These individuals may start firms themselves or license the innovation to others if they hold a patent.

At the same time, the community may be growing and attracting attention to the innovations through word of mouth, user publications or newsletters, exhibitions, or even articles in popular, trade, or scientific journals. Manufacturers of related equipment, if they exist, and their employees may observe their products being used for uses other than those originally prescribed or hear about the innovations through a variety of channels. This may lead a number of existing manufacturers and non-user innovator start-ups searching for economic rents to enter the product area. A number of firms may thus enter the emerging product area, resulting in the high entry rates observed in studies of industry evolution. Many of these firms may not be particularly innovative when it comes to product features, choosing instead to reproduce the features that others have

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31 Existing manufacturers may be of two types: those in related product categories or those with production capabilities that may be useful in mass-producing the product.

32 Several researchers have pointed out that employees of existing firms, often engineers, develop innovative products and ideas, but then find little support within the firm. Some then found new firms. It would be interesting to examine the social and professional networks of these engineers. These engineers may be better linked to a (consumer or industrial) user community than other engineers. Such a network might provide the engineer with use and need related information, solution concepts, and information suggesting who is interested and may be interested in the innovation (and for what purposes).
designed. These firms are likely to want to produce for a large market, and thus introduce novel materials and manufacturing processes and spend resources advertising and promoting the product. At this stage, open design – giving users the ability to “tinker” with the product - is critical if innovation and product alterations by users are to continue. Physical or legal (warranty) means may be used to close the design. Increased product complexity or specialized requirements (regarding tools, materials, or knowledge) may also effectively decrease the ability of users to improve the mass-produced product.

Users may be able to tap into a large, often heterogeneous community in which a variety of skills may be present; this allows for a matching of needs to resources. Firms on the other hand, are often limited to the skills and ideas of the engineers they have on staff: a group that is likely to be small and homogenous since they were likely selected because they possessed particular expertise (identified as important by managers). In some cases, users may be able to create designs that are just as sophisticated as those of manufacturers, especially if a user community includes individuals who possess engineering and design skills.

Users and user-manufacturers are likely to prioritize innovation, high-quality, and community building, while firms with other roots may be more likely to focus on building a large and, ideally, homogeneous customer base. This difference in outlook and priorities is likely to be the source of both complementary actions and tensions.

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33 To illustrate, several key windsurfing innovators, including Jake Burton and Dimitrije Milovich, rode on Sherman Poppen’s mass-manufactured “Snurfer” as kids. As they got older, they tinkered with and redesigned the Snurfer until they eventually started making boards from scratch.
FIGURE 1-3:
SUPPLEMENTARY VIEW OF THE RELATIONSHIP BETWEEN INNOVATION, FIRMS AND CHANGES IN USER PREFERENCES

Request solution from manufacturer or ignore

Users encounter different needs (wants) or use environments

Keep solution to self

Find and prototype solution alone or with others

Tell others about solution and improve it

Innovation may remain in community or be selected by firms who observe or anticipate "sufficient" market demand

Community

Existing firms
Non-user-innovator start-ups
Firms started by user-innovators

Source of change in user preferences

Firms refine design, making it more reliable and convenient to use

Consumers purchase and use product

Changes in and increased knowledge of user preferences

Open design necessary for feedback loop
1.6.1 Complementary Roles

Refinement & Production

Not surprisingly, there is a large segment of the community that is interested in using, but not making, the innovation. It appears perfectly acceptable for firms to enter the market and produce for these individuals. In some communities, manufacturers may even be seen as welcome participants; although this is likely to depend both on the culture of the particular community and the past and current behaviors of firms. User communities and early firms may also share the goal of generating interest and recognition in the product and its uses; investments in advertising, newsletters and journals, and competitions are likely to benefit both users and firms.

Characterization of the Innovation: Dimension-of-Merit vs. Novel Functionality

A dimension-of-merit innovation is an innovation that improves an existing product characteristic, e.g. making a bicycle less expensive, faster, or lighter. A functionally novel innovation is one that creates a new feature for the user, e.g. adding footstraps to a windsurfing board so that “jumping” is possible. Manufacturers, with their talented engineering and design staffs, are likely to innovate to improve dimensions-of-merit known to be of value to customers. It makes little sense for manufacturers to “guess” what functions a user might want. Users may innovate along both known dimensions-of-merit and create novel functionality.

1.6.2 Tensions: Community Priorities vs. Mass-Market Development

Community participants, user innovators, and even user-innovators who found firms are likely to value quality and the ability to change, alter or customize their products, that is they are likely to value open design. In contrast, mass manufacturers are less likely to be interested in creating customized or innovative products. They need to develop a mass market to which they can sell a generic product that can be produced cheaply and efficiently. In order to do this, they must teach new customers “what to prefer.” Manufacturers focused on the mass market may quickly begin to view communities, with their new ideas and innovations, as threatening in that they may alter the perception and culture around the product or the perception of what features are
important to the product, thereby potentially disrupting the mass-manufacturer’s distribution channels and production operations.

By making it difficult for users to alter products, mass-manufacturers gain power over the product. Only those product changes of which they approve will be introduced to the mass market and the introduction of those changes will occur on their own timeline. Mass manufacturer’s may try to achieve this in several ways, discussed below, including (1) manipulating perceptions of innovative ability, (2) making strategic design choices, and (3) property rights and government protection. By raising design and legal barriers, mass-manufacturers may not only limit user actions, but also decrease competition from firms that might otherwise emerge organically or enter the industry. These reactions are likely to create tensions with communities and result in market segmentation.

Mass manufacturers may consciously promote themselves as innovative and technically sophisticated in an effort to decrease innovation by users and increase their own power. This may be done in a variety of ways. For example, the may purchase the technology, expertise, and brand-names of innovative companies or attempt to portray the product as increasingly complex and bewildering to all but highly trained engineers and scientists. They may also express disdain for user innovations or express concern about there safety and reliability. Such claims are likely to be a source of tension between communities and mass-manufacturers, and may or may not succeed in swaying the purchasing decisions of the mass market.

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34 An early windsurfing innovator recounts: “To their credit, a lot stayed independent. But a lot of those independents were forced at some point in the future to quit or be absorbed into a bigger company. If you look around today, there aren’t that many independent companies that specialize in windsurfing equipment.”

35 See Nobel (1977) for a discussion of the professionalization of research and innovation that constructed a hierarchy that privileged manufacturers, engineers, and professional designers over users.
Mass-manufacturers are likely to promote standardized designs, since they are cheaper to produce than custom designs and have particular features that can be used to identify what a product “should” look like. Some mass manufacturers may go a step further and move towards closed (rather than open) designs that prevent users from altering the product on their own. A design that satisfies a variety of needs for the average customer and also prevents user-innovation places power over innovation squarely in the hands of the mass-manufacturer. Seen from this perspective, it is not surprising that industries tend to move towards “dominant designs.” Dominant design is currently conceptualized as the result of design choices, technological determinism, the accumulation of co-specialized assets (Teece 1986), industry regulation and government intervention, and strategic maneuvering vis-à-vis competitors (Cusumano, Mylonadis et al. 1992). We may want to include strategic choices aimed at limiting innovative behavior by users in this conceptualization.

Mass-manufacturers may also use patents, other forms of property rights protection, and warranty provisions to disrupt or threaten to disrupt a variety of user and community activities. Even if not used aggressively, the possibility of patent suits may keep some users away (Galli 2001). Government regulation and protection may also increase entry barriers for new firms and products or even define certain practices as off-limits for users, thereby “protecting” a mass manufacturer’s investments.

One effect of these behaviors is market segmentation. The mass-produced product will not satisfy the needs of at least some subset of users, who may either choose

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36 For example, the one-piece metal body severely limited the ability of the average car owner to tinker with their car. “Streamlining provided the perfect solution in the mid-1930s because it conflated style with notions of improved engineering... Streamlining privileged the machine, the designer’s vision, and the corporate image over the practical needs of the user... The harder rounder bodies of the streamlined decade proved tinker-resistant, especially after the development of all-steel bodies in the mid-1920’s. Unlike the earlier and more pliable metal-covered wooden bodies, steel bodies were virtually impervious to the average car owner’s tools (Franz 1999, pg. 209, 212-3).” Car companies followed up with advertising and propaganda aimed at communicating the efficiency and power of science and the American corporation at the expense of the user: “Science discovers, genius invents, industry applies, and man adapts himself to or is molded by new things (Franz 1999, pg. 216).”

37 See Nobel (1977) for a discussion of patent legislation and its relationship to corporate control of invention.
to produce for themselves or purchase from a specialty or custom producer. Such specialty firms are more likely to be part of or emerge from the user-community, since they serve more sophisticated and demanding users and may be run by users. As such, they may enjoy higher status - derived from their high quality products and ability to create customized and even innovative products - among community participants and possibly even among some subset of mass-market consumers. Over time, the mass-manufacturer’s product may become increasingly out of line with consumer demands, opening the door for other firms. Alternatively, a mass-manufacturer may monitor developing trends within communities and incorporate these into its own product offerings.

Section 1.7: Conclusion

This paper introduces the idea that communities may serve as an innovation development and selection mechanism and puts a social context around information acquisition that occurs prior to entrepreneurial activity by users. The many hands of communities act independently of the visible hands of firms and the invisible hand of the market; however the actions of firms may influence communities and the actions of communities may influence firms.

The process model of community-based innovation presented in this paper is based on an in-depth study of innovations in three sports. Studies of the automotive industry (Kline and Pinch 1996; Franz 1999) and several industrial products industries (von Hippel 1988) also informed the model. Data in this area are limited and further research and testing is required. In addition to deepening understanding of the patterns discussed in Section 1.6, future research might examine the methods by which firms and user-communities can work cooperatively, variations and similarities in social structure across different user communities, and the ways in which firms run by user-innovators and hobbyists behave differently from profit-seeking firms.
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Appendix: Sample of Innovations

**TABLE 1-8:**
SAMPLE OF INNOVATIONS

<table>
<thead>
<tr>
<th>Sport</th>
<th>Year</th>
<th>Innovation</th>
<th>Innovator</th>
<th>Affiliation</th>
<th>Locus of Innovation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Skateboarding</td>
<td>Early 1900s</td>
<td>Putting skates on a 2x4</td>
<td>Many children</td>
<td>None</td>
<td>Users</td>
</tr>
<tr>
<td></td>
<td>Late 1960s</td>
<td>Kicktail</td>
<td>Larry Stevenson</td>
<td>Makaha Skateboards</td>
<td>User-Founded Firm</td>
</tr>
<tr>
<td></td>
<td>1970</td>
<td>Urethane Wheels</td>
<td>Frank Nasworthy</td>
<td>None</td>
<td>User</td>
</tr>
<tr>
<td></td>
<td>Between 1973-1975</td>
<td>Precision Ball Bearings</td>
<td>Jay Shurman</td>
<td>NHS</td>
<td>Existing Manufacturer</td>
</tr>
<tr>
<td></td>
<td>1973; 1976</td>
<td>Wider Boards/Laminated Plywood</td>
<td>Lonnie Toft &amp; Willie Winkel</td>
<td>Pro-skater for Sims &amp; Wee Willi Winkel Skateboards</td>
<td>User-Founded Firm</td>
</tr>
<tr>
<td></td>
<td>Between 1975-78</td>
<td>Lighter Boards/Laminated Plywood</td>
<td>Wes Humpston and Jim Muir</td>
<td>Dogtown Skates</td>
<td>User-Founded Firm</td>
</tr>
<tr>
<td></td>
<td>1978</td>
<td>Truck Developments</td>
<td>John Hutson, Jay Shurman, Rich Nokak</td>
<td>NHS (marketed as &quot;Independent&quot;)</td>
<td>Existing Manufacturer</td>
</tr>
<tr>
<td>Snowboarding</td>
<td>Early 1900s (or earlier)</td>
<td>Standing up while sledding</td>
<td>Many children and a few adults</td>
<td>NA</td>
<td>Users</td>
</tr>
<tr>
<td>--------------</td>
<td>--------------------------</td>
<td>-----------------------------</td>
<td>-------------------------------</td>
<td>----</td>
<td>-------</td>
</tr>
<tr>
<td>1965</td>
<td>Snurfer</td>
<td>Sherman Poppen</td>
<td>None</td>
<td></td>
<td>User</td>
</tr>
<tr>
<td>1970</td>
<td>Metal/Steel Edges</td>
<td>Dimitrije Milovich</td>
<td>Winterstick</td>
<td></td>
<td>User-Founded Firm</td>
</tr>
<tr>
<td>Mid-1970s</td>
<td>Huge Side Cuts</td>
<td>Chris Sanders; Mike Olsen; Dimitrije Milovich</td>
<td>Gnu Snowboards; Avalanche; Winterstick</td>
<td></td>
<td>User-Founded Firms</td>
</tr>
<tr>
<td>1978</td>
<td>Rubber Bindings/Footstraps</td>
<td>Jake Burton; Willi Winkel</td>
<td>Burton Snowboards; Wee Willi Winkel Skateboards</td>
<td></td>
<td>User-Founded Firms</td>
</tr>
<tr>
<td>Pre-1980</td>
<td>Polyethylene Base</td>
<td>Burton Snowboards; Dimitrije Milovich</td>
<td>Burton; Winterstick</td>
<td></td>
<td>User-Founded firms</td>
</tr>
<tr>
<td>1983</td>
<td>Hybak</td>
<td>Jeff Grell</td>
<td>None (bindings first used on Flite snowboards and later developed for Sims snowboards)</td>
<td></td>
<td>User</td>
</tr>
<tr>
<td>1995</td>
<td>Central attachment of the binding/central disk system</td>
<td>Burton employees; F2 employees</td>
<td>Burton Snowboards; F2</td>
<td></td>
<td>Manufacturer (for the sport of snowboarding) and existing manufacturer</td>
</tr>
<tr>
<td>Approx. 1995</td>
<td>Flap Ratchet</td>
<td>Burton employee – David Dodge</td>
<td>Burton Snowboards</td>
<td></td>
<td>Manufacturer (for the sport of snowboarding)</td>
</tr>
<tr>
<td>Mid-1990s</td>
<td>Step-in Binding</td>
<td>Engineer at Shimano &amp; K2 employees</td>
<td>Shimano &amp; K2</td>
<td></td>
<td>Existing Manufacturers</td>
</tr>
<tr>
<td>Year</td>
<td>Description</td>
<td>Inventor(s)</td>
<td>Manufacturer</td>
<td>Founder Type</td>
<td></td>
</tr>
<tr>
<td>-------</td>
<td>-----------------------------------------------------------------------------</td>
<td>------------------------------------------</td>
<td>------------------------------------</td>
<td>--------------------------</td>
<td></td>
</tr>
<tr>
<td>1964</td>
<td>First of Type Windsurfer (the Universal Joint)</td>
<td>Newman Darby</td>
<td>Darby Industries</td>
<td>User</td>
<td></td>
</tr>
<tr>
<td>1967</td>
<td>Wishbone booms used for windsurfing</td>
<td>Jim Drake</td>
<td>None (joint patent with Hoyle Schweitzer of Windsurfing International)</td>
<td>User</td>
<td></td>
</tr>
<tr>
<td>Early 1970s</td>
<td>Eliminating the Dagger board</td>
<td>The Hawaiians</td>
<td>Windsurfing Hawaii</td>
<td>User-Founded Firm</td>
<td></td>
</tr>
<tr>
<td>1975</td>
<td>Retractable Dagger board</td>
<td>Mike Horgan</td>
<td>Windsurfing Hawaii</td>
<td>User-Founded Firm</td>
<td></td>
</tr>
<tr>
<td>1975</td>
<td>Full View Windows in Sails</td>
<td>Pat Love &amp; Mike Horgan</td>
<td>Windsurfing Hawaii</td>
<td>User-Founded Firm</td>
<td></td>
</tr>
<tr>
<td>1975</td>
<td>Volcano Pads</td>
<td>The Hawaiians</td>
<td>Windsurfing Hawaii</td>
<td>User-Founded Firm</td>
<td></td>
</tr>
<tr>
<td>1976</td>
<td>Bungeed Uphaul</td>
<td>Mike Horgan</td>
<td>Windsurfing Hawaii</td>
<td>User-Founded Firm</td>
<td></td>
</tr>
<tr>
<td>1977</td>
<td>Footstraps</td>
<td>Larry Stanley</td>
<td>Windsurfing Hawaii</td>
<td>User-Founded Firm</td>
<td></td>
</tr>
<tr>
<td>1977</td>
<td>High Clew Surf Sails/High Wind Sails</td>
<td>Pat Love &amp; Larry Stanley &amp; Mike Horgan</td>
<td>Windsurfing Hawaii</td>
<td>User-Founded Firm</td>
<td></td>
</tr>
<tr>
<td>1979</td>
<td>Higher Aspect Sails</td>
<td>Barry Spanier &amp; Jeff Bourne</td>
<td>Maui Sails</td>
<td>Existing Manufacturer</td>
<td></td>
</tr>
<tr>
<td>1979</td>
<td>Adjustable Booms</td>
<td>Larry Stanley &amp; Ken Winner</td>
<td>Windsurfing Hawaii &amp; Pro-windsurfer (affiliated with multiple manufacturers)</td>
<td>Other (user-founded firm &amp; pro)</td>
<td></td>
</tr>
<tr>
<td>1979</td>
<td>Spreader Bar, Stainless Steel and Plastic</td>
<td>Mike Horgan</td>
<td>Windsurfing Hawaii</td>
<td>User-Founded Firm</td>
<td></td>
</tr>
<tr>
<td>Late 1970s</td>
<td>Fully Battened Sails (NS)</td>
<td>Pat Love</td>
<td>Windsurfing Hawaii</td>
<td>User-Founded Firm</td>
<td></td>
</tr>
<tr>
<td>1980</td>
<td>Polyurethane Universal</td>
<td>Dave Dominy</td>
<td>Streamlined</td>
<td>User</td>
<td></td>
</tr>
<tr>
<td>1980</td>
<td>Forefin</td>
<td>Larry Stanley</td>
<td>Windsurfing Hawaii</td>
<td>User-Founded Firm</td>
<td></td>
</tr>
<tr>
<td>1980</td>
<td>Adjustable Mast Base</td>
<td>Larry Stanley &amp; Mike Horgan</td>
<td>Windsurfing Hawaii</td>
<td>User-Founded Firm</td>
<td></td>
</tr>
<tr>
<td>1981</td>
<td>Adjustable Mast Track</td>
<td>Ken Winner; unnamed North shore boardshaper on Oahu</td>
<td>Pro-windsurfer (affiliated with multiple manufacturers); Independent board shapers</td>
<td>Other (pro; user-founded firm)</td>
<td></td>
</tr>
<tr>
<td>Approx. 1981</td>
<td>Cutaway Fin</td>
<td>Graham Allen</td>
<td>None</td>
<td>User</td>
<td></td>
</tr>
<tr>
<td>Year</td>
<td>Category</td>
<td>Manufacturer/Inventor</td>
<td>Distributor/Key Innovator</td>
<td>Type/Comment</td>
<td></td>
</tr>
<tr>
<td>-------</td>
<td>------------------------</td>
<td>------------------------------------------</td>
<td>----------------------------------------</td>
<td>-------------------------------------</td>
<td></td>
</tr>
<tr>
<td>1981-2</td>
<td>&quot;Hybrid&quot; Harness</td>
<td>Barry Spanier (pure hip harness); Larry Stanley (&quot;Add-On Speedseat/Chest Harness Combo - a combination of hip, waist and chest harnesses to create the hybrid type of harness that is used today)</td>
<td>Maui Sails; Windsurfing Hawaii</td>
<td>Other (existing manufacturer, user-founded firm)</td>
<td></td>
</tr>
<tr>
<td>1982</td>
<td>Sail Materials: Laminated Fibers</td>
<td>Barry Spanier &amp; Jeff Bourne</td>
<td>Both with Maui Sails and Neil Pryde</td>
<td>Existing Manufacturer</td>
<td></td>
</tr>
<tr>
<td>1984</td>
<td>Clamp-on Boom Front End</td>
<td>Barry Spanier</td>
<td>Maui Sails and Neil Pryde</td>
<td>Existing Manufacturer</td>
<td></td>
</tr>
<tr>
<td>1984</td>
<td>RAF Sails</td>
<td>Barry Spanier &amp; Jeff Bourne</td>
<td>Both with Maui Sails and Neil Pryde</td>
<td>Existing Manufacturer</td>
<td></td>
</tr>
<tr>
<td>1984</td>
<td>Camber Inducers</td>
<td>Jeff Magnan; Thomas Nishimura; Jeff Belvedere</td>
<td>Gaastra; NA; NA</td>
<td>Other, NA; NA</td>
<td></td>
</tr>
<tr>
<td>1985</td>
<td>ADTR</td>
<td>Jeff Magnan &amp; Chuck Stahl</td>
<td>Consultants for Gaastra</td>
<td>Other (consulting for an existing manufacturer)</td>
<td></td>
</tr>
<tr>
<td>1985</td>
<td>Fin Boxes</td>
<td>Larry Tuttle</td>
<td>FinWorks</td>
<td>Existing Manufacturer</td>
<td></td>
</tr>
<tr>
<td>1985</td>
<td>Carbon-Fiber Masts</td>
<td>Peter Quigley &amp; Nevin Sayre</td>
<td>Fiberspar</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td>1986</td>
<td>Boom Materials – Carbon Fiber</td>
<td>Peter Quigley &amp; Nevin Sayre</td>
<td>FiberSpar</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td>Approx. 1988*</td>
<td>Sail Materials: Polyester Film</td>
<td>Peter Brockhaus</td>
<td>F2</td>
<td>Manufacturer (for the sport of windsurfing)</td>
<td></td>
</tr>
<tr>
<td>1980s (verify with notes)</td>
<td>Flapper/Anti-Ventilation Device</td>
<td>Ken Winner</td>
<td>Pro-windsurfer (affiliated with multiple manufacturers)</td>
<td>Other (Pro)</td>
<td></td>
</tr>
<tr>
<td>late 1990s</td>
<td>Beginner Board/Windglider</td>
<td>Ken Winner &amp; Dave Johnson</td>
<td>Pro-windsurfer &amp; North Sports (verify)</td>
<td>Other (in-industry manufacturer &amp; a pro)</td>
<td></td>
</tr>
<tr>
<td>Approx. 1998</td>
<td>Sheer-Tip Rigs/Flex Top Sail</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td>NA</td>
<td>High Performance Fins</td>
<td>Bill Bahne &amp; Curtis Hesselgrave</td>
<td>Bahne</td>
<td>Existing Manufacturer</td>
<td></td>
</tr>
<tr>
<td>NA</td>
<td>Wingmast</td>
<td>Dimitrije Milovich; Ernst Meyer (Swiss)</td>
<td>NA</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td>NA</td>
<td>Lighter Boards/Sandwich Construction</td>
<td>John Parton &amp; Ian Pitkamin</td>
<td>ProTech</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td>NA</td>
<td>Boom Materials &amp; Design – Aluminum</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td>NA</td>
<td>Blade Fin</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td>Windsurfing (Cont')</td>
<td>NA</td>
<td>Short High Performance Boards</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>--------------------</td>
<td>----</td>
<td>--------------------------------</td>
<td>----</td>
<td>----</td>
<td>----</td>
</tr>
<tr>
<td>NA</td>
<td>NA</td>
<td>Kitesurfing</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
</tbody>
</table>

* 1986 according to Neil Pryde, 1988 according to Barry Spanier.
CHAPTER 2

HOW COMMUNITIES SUPPORT INNOVATIVE ACTIVITIES:
AN EXPLORATION OF ASSISTANCE & SHARING AMONG END-USERS

NIKOLAUS FRANKE & SONALI SHAH

Abstract

This study contributes to our understanding of the innovation process by bringing attention to and investigating the process by which innovators outside of firms obtain innovation-related resources and assistance. This study is the first to explicitly examine how user-innovators gather the information and assistance they need to develop their ideas and how they share and diffuse the resulting innovations. Specifically, this exploratory study analyzes the context within which individuals who belong to voluntary special-interest communities develop sports-related consumer product innovations. We find that these individuals often prototype novel sports-related products and that they receive assistance in developing their innovations from fellow community members. Innovation-related information and assistance, as well as the innovations themselves, are freely shared within these communities. The nature of these voluntary communities and the "institutional" structure supporting innovation and free sharing of innovations is likely to be of interest to innovation researchers and managers both within and beyond this product arena.
Section 2.1: Introduction

Academics and practitioners alike express interest in uncovering, explaining, and potentially manipulating the sources of innovation. Research has shown that many important industrial product and process innovations are developed within firms where the product is used, rather than by firms who manufacturer the product for sale to others (von Hippel 1988). Two recent studies focusing on innovation in sporting equipment document a parallel pattern in consumer products and bring attention to the fact that consumers also innovate. These two studies show that many major innovations in sports equipment are made by end-users rather than firms and that a large fraction of consumers do innovate in some way (Luthje 2000; Shah 2000).

Much research has focused on the provision of resources in product development organizations (Brown and Eisenhardt 1995); inter- and intra-firm product development-related communications (Allen 1971; Allen 1977; Ancona and Caldwell 1992); and even on the emergence of informal “skunk works” within the formal organization. The finding that users may also innovate in consumer product fields raises an interesting question: do individual end users who innovate receive resources and support from others? How do they find and “pay for” these resources? We reason that end-user innovators, like their counterparts in firms, are likely to require the assistance of others in developing their innovations. The innovations in consumer products studied by Shah were made by end-users who had no formal organizational structure or resources from which to draw; however there is evidence that they often received assistance from and worked closely with others with whom they practiced the sport. For this reason, we suspect that members of communities of sports enthusiasts might be the source of the needed support. In this study we explore this possibility38. This study is the first to explicitly examine

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38 We chose to study the innovation-related behaviors of sports enthusiasts within communities rather than individuals innovators (who may or may not belong to a community) in order to better understand the composition and structure of the community with which each innovator was involved. We are unable to comment on the relative fraction of user-innovators who are members of voluntary communities versus who do not belong to such communities or on the process by which innovators outside of communities assemble resources. In fact, it is highly likely that innovators who are not members of such communities exist and innovate very effectively either completely on their own or with the assistance of other individuals. A similar study could be conducted by sampling individual sports enthusiasts to resolve these issues.
how user-innovators who belong to voluntary special interest communities gather the information and assistance they need to develop their ideas.

This study investigates the innovation-related activities of members of four communities of sports enthusiasts who report having developed a novel sporting equipment innovation. A summary of major findings follows. Without exception, the innovating community members we surveyed do not innovate in isolation or secrecy; they receive important advice and assistance from other community members. Assistance is provided to innovators for free and innovators generally share their innovations to the community for free - although the levels of free support and access diminish somewhat as competitive pressures increase. Monetary profit is not a key motivator for either innovators or those who assisted them; instead, survey respondents cite having fun and viewing the giving of innovation-related assistance to community members as a social norm as the strongest factors influencing their decision to assist innovators. Receiving assistance appears to be a necessary, but not sufficient input into creating an innovation that diffused widely.

We propose that the phenomenon we report upon - innovation by end users within voluntary user communities - is a general and widespread phenomenon worthy of further study. The context in which the user-innovators in consumer product fields studied here innovate may serve as the functional equivalent of the multi-person innovation project teams often organized by firms to develop novel products and processes. This setting also appears to be quite similar to the context in which open source software is developed. In the open source software context, individual programmers create and improve software within multi-person "project" groups; in doing so they receive free assistance from others and freely share the product of their efforts.

In the following sections of this paper, we review the related literature (section 2.2) and describe our research sample and methods (section 2.3). We then report our findings with respect to the number of innovators in our sample, how they interact with their community, and the characteristics of their innovations (section 2.4). Next we
report our findings regarding how innovators find assistance, the skills of those who provide assistance, satisfaction with assistance received, and how receiving assistance affects innovation diffusion (section 2.5). We then discuss the factors that appear to be motivating and regulating behaviors related to the exchange of information and assistance and the free-revealing of innovation (section 2.6). Finally, we discuss the implications of our findings (section 2.7).

Section 2.2: Literature Review

2.2.1 The Sources of Innovation

Empirical research into the "functional" sources of innovation for industrial products and processes has shown that the actual developers of many industrial products and processes, which are often subsequently produced and sold by manufacturers, are users. Manufacturer-innovators expect to benefit from their innovations by selling them to others; user-innovators expect to benefit by direct use (Enos 1962; Knight 1963; Freeman 1968; Shaw 1985; von Hippel 1988). Studies continue to uncover the prevalence and importance of user innovations in industrial products and methods by which to “harness” this innovative ability (von Hippel 1986; von Hippel 1988; Herstatt and von Hippel 1992; Riggs and Hippel 1994; von Hippel, Thomke et al. 1999; Morrison 2000). Recent research indicates that users also play an important role in the development of consumer product innovations (Luthje 2000; Shah 2000).

2.2.2 Innovation within Voluntary Communities

The “communities-of-practice” literature provides an interesting parallel to the volunteer communities we study (Brown and Duguid 1991; Lave and Wenger 1991; Brown 2001). This literature argues that the ways people actually work differs fundamentally from the ways organizations describe that work in manuals, training programs, organizational charts, and job descriptions – and that a great deal of learning and innovation occur in the informal communities-of-practice focused on simply getting work done (Brown and Duguid 1991). Communities of practice exist in a variety of
settings and may develop improvements or innovations in products, services, and work practices. Some documented examples include photocopier repair technicians, clerical workers, and radiology technicians (Barley 1986; Orr 1996; Wenger 1998). The communities-of-practice literature focuses on occupational and organizational communities, while we focus on (innovation in) voluntarily-assembled communities of end-users. Both perspectives question commonly held beliefs about the nature of work, organization, learning, and innovation.

Open source communities are yet another example of a user-community in which information, assistance, and innovations are freely shared. Open source software (OSS) development projects are carried out by communities of volunteers from many different locations and organizations. These individuals develop and share code to create and improve programs. OSS development has resulted in the creation of software that may precede, displace, or serve as a substitute for commercially produced software. One benefit of participation in these communities that is often downplayed is the fun, enjoyment, and intrinsic motivation that arise through engagement in the task and community (Torvalds 1998; Lerner and Tirole 2002). The similarities between open source communities and sports communities are striking, despite the fact that one community produces physical products and is geographically concentrated, while the other produces software code and is geographically dispersed (von Hippel 2001).

2.2.3 Reasons to Freely Share Innovation-Related Information

One might expect users to guard any innovation-related information that they believe is valuable. However, Harhoff et al. argue that it may be more beneficial for an innovator to reveal such information. They offer four theoretical reasons for why this might be the case: (1) it may induce improvements by others; (2) an advantageous standard might be achieved this way; (3) it may make sense if low rivalry conditions exist; and (4) expectations of reciprocity and reputation effects might motivate

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This is not a new observation: “the distinction between the “formal” and “informal” organization of the firm is one of the oldest in the literature, and it hardly needs repeating that observers who assume firms to be structured in fact by the official organization chart are sociological babes in the woods” (Granovetter 1985, pg. 502). The existence and importance of informal structures within organizations has been noted in many classic sociological studies (Selznick 1949; Gouldner 1954; Blau 1955; Dahon 1959).
individuals to reveal (Harhoff, Henkel et al. 2000). Much empirical research lends support to this idea, showing that the sharing of such information occurs in a variety of commercial settings, leading us to expect similar and perhaps stronger, patterns within user-communities. An overview of empirical findings is provided below.

Past research on information trading and sharing between rival firms offers limited insight into what types of information and assistance may be exchanged between user-innovators and why. Work on informal information trading argues and empirically demonstrates that, under certain conditions, it makes sense to exchange existing information, even among rivals (von Hippel 1987; Schrader 1991). These studies focus on reciprocal exchange relationships where the information exchanged has relatively low competitive value: the rival could obtain this information from other sources or could relatively easily uncover the information himself.

Other studies also focus on the free-revealing of information or innovations. Allen finds that many production techniques in the nineteenth century were developed by a process called “collective invention” (Allen 1983). An essential feature of collective invention is the free-revealing of technical information to actual and potential competitors. Allen argues that it is this behavior that allowed cumulative advance and suggests that firms might even desire such behavior. Rosenkopf and Tushman examine information and knowledge sharing in the context of inter-organizational networks formed by members of voluntary cooperative groups such as task forces, technical committees and standards groups in the flight simulation industry; they find that community networks and technology co-evolve (Rosenkopf and Tushman 1998). As we can see, the free-revealing of innovations and information between firms may occur in a variety of settings and contexts.
Section 2.3: Study Methods

2.3.1 Communities Selected for Study

We had two basic criteria for choosing communities for our sample. First, in order to observe community-related innovation behavior, the community as a whole or some community members should be engaged in innovative activities. Second, we wanted to include communities that differed in their make-up (constituency) and structure in order to cover a broad range of community and user characteristics to make for more generalizable findings. We screened for these criteria by speaking with community leaders and members.

Below you will find a short description of each of the four communities we studied. Table 2-1 provides a summary of community-specific information. We are aware of no bias in our innovation pattern findings resulting from the selection of these particular communities.

Sailplaning Community

Sailplaning, which originated in the second half of the 19th century, involves one or two people flying in a (closed) sailplane. The sailplaning community we studied consists of students of technical universities in Germany who share an interest in sailplaning and building their own sailplanes. They spend a great deal of time together and share a common “student” lifestyle.

Canyoning Community

Canyoning (called canyoneering in the United States) is a new extreme sport that is quite popular in the Alps. It combines mountain climbing, abseiling (rappelling), and swimming in canyons. It is extreme in that it requires significant skill and involves physical risk. Participants do not formally race against each other.

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40 Our definition of community stems from that found in the communities of practice literature: communities of practice are seen as "groups of interdependent participants providing a work context within which members construct both shared identities and the social context that helps those identities be shared" (Brown 2001). Such a definition can apply to both formal work communities, as well as communities organized around other goals.
The community we analyzed was established in 1995 as a forum in which to organize joint activities and trips, exchange information, and provide mutual help for people who shared an interest in the new sport. Members organize trips, take part in regular “pub social”, make presentations to each other, and maintain a website. A normal trip is likely to involve 25-30 people. Each trip generally includes a different combination of community members.

**Boardercross Community**

“Boardercross” is a new extreme snowboarding sport in which six snowboarders compete simultaneously in a downhill race. Each racetrack varies, but is likely to incorporate tunnels, steep curves, water holes, jumps, etc. The (informal) community we studied consists of semi-professional athletes from all over the world who share an active interest in this sport. They meet in up to 10 competitions a year in Europe, North America, and Japan. Community members are competitive athletes and compete against one another. They spend a great deal of time together both training and taking part in leisure activities (parties). Community members are very close to one another and share very similar lifestyles.

**Handicapped Cycling Community**

Individuals with physical disabilities practice many sports. These individuals must often design or make improvements to their equipment to accommodate a variety of physical disabilities. We studied a community of semi-professional cyclists who had cerebral palsy or an amputated limb. This community is not a formal club, but community members know each other well from national and international competitions, training sessions, and seminars sponsored by the Deutscher Sportbund (German National Sports Council) for selected athletes. The community is largely comprised of competitive handicapped cyclists who often compete against one another. Although the community members are distributed all over Germany they know each other well and members feel that they are a close community.
<table>
<thead>
<tr>
<th>Community Characteristics</th>
<th>Sailplaning</th>
<th>Canyoning</th>
<th>Boardercrossing (Snowboarding)</th>
<th>Handicapped Cycling</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Professional Level</td>
<td>moderate</td>
<td>moderate</td>
<td>high</td>
<td>high</td>
<td>varies</td>
</tr>
<tr>
<td>Location</td>
<td>all over Germany</td>
<td>southern Germany</td>
<td>worldwide</td>
<td>all over Germany</td>
<td>varies</td>
</tr>
<tr>
<td>Formal Ties (e.g. club)</td>
<td>yes</td>
<td>yes</td>
<td>no</td>
<td>no</td>
<td>varies</td>
</tr>
<tr>
<td>Level of Competition</td>
<td>low</td>
<td>low</td>
<td>high</td>
<td>high</td>
<td>varies</td>
</tr>
<tr>
<td>Level of Interaction</td>
<td>close</td>
<td>Close</td>
<td>close</td>
<td>varies</td>
<td>quite close</td>
</tr>
<tr>
<td>Technical Complexity of Equipment</td>
<td>very high</td>
<td>low</td>
<td>moderate</td>
<td>moderate</td>
<td>varies</td>
</tr>
<tr>
<td>Outside Users who Might Provide Information and Assistance</td>
<td>one of the other 552 sailplane clubs in Germany</td>
<td>approx. 1000 at same level in same region</td>
<td>approx. 800 at same level in same region</td>
<td>unknown</td>
<td>many</td>
</tr>
<tr>
<td>Average Respondent Age</td>
<td>25.1</td>
<td>39.3</td>
<td>22.8</td>
<td>33.5</td>
<td>varies</td>
</tr>
<tr>
<td>Female Respondents</td>
<td>10.5%</td>
<td>25.6%</td>
<td>48.8%</td>
<td>10.5%</td>
<td>23.1%</td>
</tr>
</tbody>
</table>

**Sample Characteristics**

<table>
<thead>
<tr>
<th>Community Size (N)</th>
<th>170</th>
<th>123</th>
<th>170</th>
<th>58</th>
<th>521</th>
</tr>
</thead>
<tbody>
<tr>
<td>Responses (n)</td>
<td>87</td>
<td>43</td>
<td>48</td>
<td>19</td>
<td>197</td>
</tr>
<tr>
<td>Response Rate (n/N)</td>
<td>51.1%</td>
<td>35.0%</td>
<td>29.4%</td>
<td>32.8%</td>
<td>37.8%</td>
</tr>
<tr>
<td>Innovators as Percent of Respondents</td>
<td>41.4%</td>
<td>30.2%</td>
<td>18.2%</td>
<td>26.3%</td>
<td>32.1%</td>
</tr>
</tbody>
</table>
2.3.2 Data Collection

After selecting the four communities described above, we conducted several qualitative interviews in order develop a deeper understanding of the role of communities in the innovation process. We contacted community leaders and questioned them about the best way to contact individual members. As a result, paper questionnaires were mailed to members of the sailplanning, canyoning, and handicapped cyclist communities, while members of the boardercross community were sent an e-mail describing the nature of the study and containing a link to an on-line version of the questionnaire.

The questionnaires distributed to the different groups contained the same questions and information regarding the study. The questionnaire had four parts. In the first and final parts, all respondents were asked about their personal characteristics as well as their community behavior and attitude. The second part was for innovators only. In this section we asked innovators to answer innovation-related questions with respect to the most important innovation he or she has made\(^{41}\). The third part of the study was for individuals who had assisted in the development of an innovation only\(^{42}\). The questionnaire was anonymous and respondents were assured that their innovative ideas would not be shared with manufacturers. All questionnaires were distributed in December 2000. Respondents were reminded to complete the survey two weeks later via personal contact, telephone, e-mail, or mail. An overall response rate of 37.8% was obtained.

Despite the satisfactory response rate, there is a possibility of self-selection, e.g. in favor of individuals involved in the innovation process because potentially proud innovators may be more likely to respond. Such self-selection would result in a disproportionately high rate of innovators (and innovations) in the sample. While we have no information about non-respondents, several things indicate that the data does not

\(^{41}\) In the remainder of the paper we will use the term “he” and “his” for simplicity, although both male and female innovators and non-innovators were present in the sample.

\(^{42}\) For survey details see Appendix.
suffer from such bias. First, it has been argued that late respondents who answer only after receiving several reminders are similar to non-respondents (Hendricks 1949). An analysis of early versus late respondents did not show any significant difference between these two groups. Second, in order to prevent non-innovators from feeling that the survey was not relevant to them and thus not responding, the first section of the questionnaire purposefully did not deal with innovation at all and focused on the individual and his relationship with the community. Third, the literature on user innovation suggests that innovators are likely to have "lead user" characteristics that differentiate them from non-innovators. Thus, the possession of lead user characteristics by a large fraction of respondents might indicate bias within the sample\(^\text{43}\). Instead we find that there is no bias towards lead users in the sample: on average, innovators exhibit these characteristics more strongly than non-innovators (as would be expected), and the average values exhibited by non-innovators on these characteristics are above the middle of the scale (indicating less agreement with the characteristics) without exception (Table 2-3). Fourth, while 39% of the respondents reported innovating and/or assisting in the innovation process (Table 2-7), a full 61% of respondents did not engage in these activities. Thus the sample consists of both individuals involved in the innovation process and individuals who were not involved. Finally, we would like to point out that even if all non-respondents had no involvement in the innovation process, our findings regarding the process of community based innovation and the motivations of individuals involved in this process – the central focus of this paper - are unlikely to be affected\(^\text{44}\).

\(^{43}\) We thank an anonymous referee for suggesting this "test."

\(^{44}\) We do not believe that the relative novelty and culture of these sports are responsible for the innovation rate we observe (section 4.1); a similar innovation rate is reported in a study of innovation among individuals involved in a very mainstream athletic activity - hiking and trekking (Luthje 2000). It is possible that the relative novelty and culture of these sports may increase the likelihood that an individual chooses to participate in a community, however note that community participation is not at all unique to novel sports: for example, runners often join running clubs and tennis enthusiasts often join tennis clubs. Overall, we are not aware of any bias resulting from either the choice of these four sports communities or from self-selection that influence our findings.
Section 2.4: Findings: The Innovators & Their Innovations

Innovation is a relatively common activity in the four communities studied: almost one-third of all respondents report having innovated. As one would expect many of these innovations were improvements to existing products, but a surprisingly high percentage of innovators created totally new products. Interestingly, innovators and non-innovators differ significantly in their community-oriented behaviors. In this section, we provide data that support these findings.

2.4.1 The Innovations

Over 40% of the innovations reported in our sample solve urgent problems for their innovators and one in seven (14.5%) innovations is considered to be a completely new product by their innovator. Many of the innovators see potential for the sale of their innovation on the mass market and almost one-quarter of the innovations are currently or will soon be produced for sale by a manufacturer, and can thus be thought of as having some mainstream or niche market appeal. We asked innovators to provide a short description of their innovations and assess them along several dimensions; the results are shown in Table 2-2.

Since we asked each innovator to tell us about his most important innovation, (1) the proportion of commercialized or soon to be commercialized innovations, given the complete set of innovations produced by members of these communities, might be overestimated and (2) the total number of commercialized user innovations might actually be underestimated, since it is possible that some user(s) developed more than one innovation that was subsequently commercialized.
<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Descriptive Statistics</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Newness&lt;sup&gt;a&lt;/sup&gt;</td>
<td>Mean: 3.56, Median: 3.5</td>
<td>Completely new product: e.g. new emergency system where pilot gets out of the cockpit with a rocket (sailplanning)</td>
</tr>
<tr>
<td></td>
<td>High Agreement: 14.5%</td>
<td>Small improvement: e.g. better rucksack (canyoning)</td>
</tr>
<tr>
<td>Urgency&lt;sup&gt;b&lt;/sup&gt;</td>
<td>Mean: 4.79, Median: 5.0</td>
<td>High urgency: e.g. new brake system for arm-amputated (handicapped cycling)</td>
</tr>
<tr>
<td></td>
<td>High Agreement: 41.9%</td>
<td>Low urgency: e.g. new ventilation system for cockpit (sailplanning)</td>
</tr>
<tr>
<td>Market Potential&lt;sup&gt;c&lt;/sup&gt;</td>
<td>Mean: 3.44, Median: 4.0</td>
<td>High market potential: e.g. improved boots and binding (snowboarding)</td>
</tr>
<tr>
<td></td>
<td>High Agreement: 24.2%</td>
<td>Small market potential: e.g. disrupt fixed rope with chemical (etching)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(canyoning)</td>
</tr>
<tr>
<td>Commercialization</td>
<td>23.1% of the innovations are currently or will soon be produced for sale by a manufacturer</td>
<td>E.g. new shoe which is seamless, high-frequency welded and offers better protection of the leap joint</td>
</tr>
</tbody>
</table>

<sup>a</sup> self-rating, 7-point rating scale: 1 = small improvement of existing product; 7 = completely new product; n = 60.

<sup>b</sup> self-rating, 7-point rating scale: 1 = solves minor problems; 7 = solves acute problems; n = 60.

<sup>c</sup> self-rating, 7-point rating scale: 1 = very small; 7 = very big; n = 60.
2.4.2 The Innovators

Innovators appear to be different from non-innovators at both the individual and community level. At the individual level, innovators in our sample possess "lead user" characteristics that differentiate them from non-innovators (Table 2-3). Lead users are a relatively small fraction of users who are highly likely to innovate. They are likely to be ahead of product or service trends and benefit greatly from the advent of new products or services (von Hippel 1986).

The way in which an innovator interacts with his community and how he thinks the community perceives him also differentiates the innovator from the non-innovator (Table 2-3). Innovators spend significantly more time with other community members than do non-innovators; specifically they spend 32% (10 days per year) more time per year in the community. In addition, innovators have been members of the community 30% (1.3 years) longer than non-innovators. It appears that time with the community is associated with the likelihood of innovating. This interpretation is supported by the findings that innovators report taking a more active part in the community, partake in more non-sport related activities with other community members, and feel more strongly that the community takes their opinion into account when making decisions than do non-innovators.45

These findings alone do not necessarily mean that community has a causal impact on the likelihood of innovation. Instead, it could be the case that innovators work in total isolation and develop a reputation for their efforts among their peers, thus leading to a more central position in the community. Section 2.5 addresses this concern.

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45 T-tests clearly show that the innovators have significantly higher needs for new products and are far ahead of the trend. They are lead users (von Hippel 1986).
<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Innovators&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Non-Innovators&lt;sup&gt;b&lt;/sup&gt;</th>
<th>Difference&lt;sup&gt;c&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Lead User Characteristics (1): Being Ahead of the Trend&lt;sup&gt;d&lt;/sup&gt;</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>“I usually find out about new products and solutions earlier than others.”</td>
<td>2.71</td>
<td>4.03</td>
<td>p &lt; 0.001</td>
</tr>
<tr>
<td>“I have benefited significantly by the early adoption and use of new products.”</td>
<td>3.58</td>
<td>4.34</td>
<td>p &lt; 0.01</td>
</tr>
<tr>
<td>“I have tested prototype versions of new products for manufacturers.”</td>
<td>4.94</td>
<td>5.65</td>
<td>p &lt; 0.05</td>
</tr>
<tr>
<td>“In my sport I am regarded as being on the “cutting edge”.”</td>
<td>4.56</td>
<td>5.38</td>
<td>p &lt; 0.01</td>
</tr>
<tr>
<td>“I improved and developed new techniques in Boardercrossing.”</td>
<td>4.29</td>
<td>5.84</td>
<td>p &lt; 0.001</td>
</tr>
<tr>
<td><strong>Lead User Characteristics (2): High Benefit from Innovation&lt;sup&gt;d&lt;/sup&gt;</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>“I have new needs which are not satisfied by existing products.”</td>
<td>3.27</td>
<td>4.38</td>
<td>p &lt; 0.001</td>
</tr>
<tr>
<td>“I am dissatisfied with the existing equipment.”</td>
<td>3.90</td>
<td>5.13</td>
<td>p &lt; 0.001</td>
</tr>
<tr>
<td><strong>Time in Community</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Years as a community member</td>
<td>4.46</td>
<td>3.17</td>
<td>p &lt; 0.01</td>
</tr>
<tr>
<td>Days per year spent with community members</td>
<td>43.07</td>
<td>32.73</td>
<td>p &lt; 0.05</td>
</tr>
<tr>
<td>Days per year spent participating in the sport</td>
<td>72.48</td>
<td>68.71</td>
<td>n.s.</td>
</tr>
<tr>
<td><strong>Role in Community&lt;sup&gt;d&lt;/sup&gt;</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>“I am a very active member of the community”</td>
<td>2.85</td>
<td>3.82</td>
<td>P &lt; 0.01</td>
</tr>
<tr>
<td>“I get together with members of the community for activities that are not related to the sport (movies, dinner parties, etc.)”</td>
<td>3.39</td>
<td>4.14</td>
<td>p &lt; 0.05</td>
</tr>
<tr>
<td>“The community takes my opinion into account when making decisions”</td>
<td>2.89</td>
<td>3.61</td>
<td>p &lt; 0.05</td>
</tr>
</tbody>
</table>

<sup>a</sup> all values are means; n = 60.

<sup>b</sup> all values are means; n = 129.

<sup>c</sup> 2-tailed t-tests for independent samples.

<sup>d</sup> 7-point rating scale: 1 = very accurate; 7 = not accurate at all.
Section 2.5: Findings: The Sources and Importance of Assistance

An individual may develop an idea, but developing this idea into a functioning prototype often requires the assistance of others. We find that, within user communities, user innovation is not an individual task but a joint effort. All the innovators in our sample receive assistance from other individuals during the innovation process. Receiving assistance from three to five people is most common (Table 2-4). In Sections 2.5.1 and 2.5.2 we show that belonging to a community gives the innovator clear and tangible benefits in obtaining quality innovation-related assistance and that this assistance often comes from other innovative individuals. In Section 2.5.3 we show that innovators report high levels of satisfaction with the assistance they received. In Section 2.5.4 we discuss the impact of assistance of the diffusion of the innovation.

TABLE 2-4: INNOVATORS RECEIVE ASSISTANCE

<table>
<thead>
<tr>
<th>Innovators Receive Assistance From</th>
<th>Number of Cases</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 persons</td>
<td>0</td>
<td>0%</td>
</tr>
<tr>
<td>1 person</td>
<td>3</td>
<td>6%</td>
</tr>
<tr>
<td>2 people</td>
<td>14</td>
<td>26%</td>
</tr>
<tr>
<td>3 to 5 people</td>
<td>25</td>
<td>47%</td>
</tr>
<tr>
<td>6 to 10 people</td>
<td>8</td>
<td>15%</td>
</tr>
<tr>
<td>Over 10 people</td>
<td>3</td>
<td>6%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>53</strong></td>
<td><strong>100%</strong></td>
</tr>
</tbody>
</table>

2.5.1 Community Membership Helps Innovators Find Assistance

Belonging to a community offers the innovator two key benefits in finding innovation-related assistance: (1) other community members offer assistance directly, and (2) other community members refer the innovator to individuals they know outside of the community.

Specifically, 63.5% of innovators report that belonging to the community helped them find individuals who made contributions to their innovation (Table 2-5). The most
important assistance received was as likely to come from individuals outside the community as it was to come from community members.

We find that 11.4% of the innovators report that the most important information and assistance they received came from individuals who were initially strangers; 32.4% report that this came from individuals who were initially close friends (Table 2-5). This indicates that community members introduce the innovator to other individuals who may be able to provide assistance - community actively helps the innovator find the assistance he needs and innovators are therefore not “restricted” to working with individuals with whom they have a personal relationship (friendship), have worked with before, or have assisted before.

**TABLE 2-5: RELATIONSHIPS WITH THOSE WHO GIVE ASSISTANCE**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>Median</th>
<th>High Agreement</th>
<th>Low Agreement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Community Membership Helps in Finding Assistance&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2.88</td>
<td>2</td>
<td>63.5%</td>
<td>19.2%</td>
</tr>
<tr>
<td>Community Members as a Source of Information&lt;sup&gt;b&lt;/sup&gt;</td>
<td>3.70</td>
<td>3</td>
<td>47.7%</td>
<td>29.5%</td>
</tr>
<tr>
<td>Friendship Status&lt;sup&gt;c&lt;/sup&gt;</td>
<td>3.30</td>
<td>3</td>
<td>32.4%</td>
<td>11.4%</td>
</tr>
</tbody>
</table>

<sup>a</sup> “Belonging to the community helped me find people who contributed to my idea/improvement”; 7-point rating scale: 1 = very accurate; 7 = not accurate at all; n = 52.

<sup>b</sup> 7-point rating scale: 1 = most of the important information came from community members; 7 = ... non-community members; n = 44.

<sup>c</sup> 7-point rating scale: 1 = most of the important information came from initially close friends; 7 = ... initially strangers; n = 53.
2.5.2 Skills of Those Who Gave Assistance

Most innovators report receiving assistance from individuals who are creative and innovative, possess skills complementary to their own, and often have expertise that was useful in developing the innovation (Table 2-6).

If those who give assistance are in fact as creative and innovative as innovators report, we should observe innovating behavior among those who assist. We do indeed find statistically significant evidence to support this: of the 41 individuals who gave assistance, over two-thirds were also innovators (Table 2-7). And, of the 60 innovators, almost half gave assistance to others.

The high satisfaction expressed by innovators who received help, the highly regarded skills of those who gave assistance, and the relatively high number of individuals taking part in assisting and/or innovating activities (38.8%) shows that the system of mutual help in the communities works well.

### TABLE 2-6:

<table>
<thead>
<tr>
<th>SKILLS OF THOSE WHO GIVE ASSISTANCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variable</td>
</tr>
<tr>
<td>-------------------------------------</td>
</tr>
<tr>
<td>Creative &amp; Innovative(^a)</td>
</tr>
<tr>
<td>Complementary Skills(^b)</td>
</tr>
<tr>
<td>Expert Status(^c)</td>
</tr>
</tbody>
</table>

\(^a\) "The people who helped me are creative and innovative themselves"; 7-point rating scale: 1 = very accurate; 7 = not accurate at all; n = 53.

\(^b\) "The people who helped me have skills that are complementary to mine"; 7-point rating scale: 1 = very accurate; 7 = not accurate at all; n = 53.

\(^c\) 7-point rating scale: 1 = most of the important information came from experts; 7 = ... non-experts; n = 53.
TABLE 2-7:  
RELATIONSHIP BETWEEN INNOVATING AND GIVING INNOVATION RELATED ASSISTANCE

<table>
<thead>
<tr>
<th></th>
<th>Innovators</th>
<th>Non-Innovators</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gave Assistance</td>
<td>28</td>
<td>13</td>
<td>41</td>
</tr>
<tr>
<td>Did Not Give Assistance</td>
<td>32</td>
<td>115</td>
<td>147</td>
</tr>
<tr>
<td>Total</td>
<td>60</td>
<td>128</td>
<td></td>
</tr>
</tbody>
</table>

n = 188; chi squared = 31.93; p < 0.0001

2.5.3 Innovators are Satisfied with the Assistance They Receive

Innovators report being very satisfied with the assistance they receive: 79.2% of innovators report that they would ask the same people for help again (Table 2-8). This is a preliminary indicator that assistance is not only frequently observed, but is also very important.

TABLE 2-8:  
INNOVATORS ARE SATISFIED WITH THE ASSISTANCE THEY RECEIVED

<table>
<thead>
<tr>
<th>Satisfaction with Assistance Received</th>
<th>Mean</th>
<th>Median</th>
<th>High Agreement</th>
<th>Low Agreement</th>
</tr>
</thead>
<tbody>
<tr>
<td>“If I had a similar problem I would ask the same people again”⁷⁷</td>
<td>1.89</td>
<td>2</td>
<td>79.2%</td>
<td>3.8%</td>
</tr>
</tbody>
</table>

⁷⁷ 7-point rating scale: 1 = very accurate; 7 = not accurate at all; n = 53.
2.5.4 Receiving Assistance Impacts Innovation Diffusion

Diffusion is an important element of innovation performance. It reflects the number of users interested in the innovation and the time it needs to win recognition among the users. The features of an innovation largely impact the extent and speed of its diffusion (Rogers 1983). From a manufacturer’s perspective, the extent of diffusion, combined with the amount of money each user is willing to pay and the costs of producing and selling it, constitute the profit a firm can expect from manufacturing the innovation. In addition, it could be the case that innovators report such a high degree of satisfaction with assistance received (see 5.3) for social reasons rather than the quality of the assistance itself. In this section we address this objection by showing that the amount of assistance received positively affects innovation diffusion both inside and outside the community.

Method: Measuring Innovation Diffusion

The extent to which an innovation has diffused is based on information self-reported by the innovator. We asked each innovator to report how many individuals within the community and how many individuals outside the community were using their innovation (7-point rating scales). Correlation analysis shows that an innovation used by many members of an innovator’s community is likely to be used by many individuals outside of that community as well ($r = 0.579$, $p<0.001$, $n = 49$). Thus, diffusion inside the community might be considered an early indicator of later diffusion outside the community. This high correlation allows us to aggregate these two scales and construct a “total diffusion” index without suppressing major effects. This new variable (total diffusion) is our dependent measure of innovation diffusion.

---

46 Diffusion is related to other measures of innovation performance. There are three other variables which can be regarded as partial measures of innovation performance, which we expect and find to be correlated with total diffusion: the newness of the innovation as assessed by the innovator ($r = 0.298$, $p<0.05$), the market potential of the innovation as assessed by the innovator ($r = 0.259$, $p<0.05$), and whether or not the innovation has yet been commercialized ($r = 0.368$, $p<0.01$).
Threshold or Linear Relationship?

Our findings suggest that receiving assistance from the community is a necessary but not sufficient precondition for innovation diffusion: a threshold pattern, rather than a linear pattern, describes the relationship between the level of assistance by the community and the diffusion of the innovation. In order to analyze the relationship between assistance and diffusion, crosstab analyses for different measures of assistance and diffusion are performed.

An example of a crosstab analysis is displayed in Table 2-9. When reading the table, note that a clustering of cases along the diagonal would indicate a linear relationship; a clustering above the diagonal a necessary but not sufficient threshold relationship; and cases below the diagonal tell that the innovation diffused although the innovator received little assistance. The crosstab results for the level of encouragement received versus diffusion indicate that there is virtually no linear relationship between these two variables (Table 2-9). An OLS regression supports this point.

A clear relationship does exist in the data in the form of a striking threshold pattern (Table 2-9). The amount of assistance appears to form an upper bound for diffusion: the relationship is “assistance is necessary but not sufficient for innovation diffusion” not “the more assistance, the better the innovation diffuses.” This makes sense because assistance will improve the quality of an innovation to a limited degree, but even an unlimited amount of assistance will not turn a poor idea into a breakthrough innovation or turn an idea with limited consumer interest into a blockbuster. We perform this analysis for other forms of assistance as well and find similar patterns (Table 2-10). Results show clearly that assistance by the community does not “guarantee” diffusion, but less assistance might be associated with more limited diffusion.

---

47 There are almost no innovations along the diagonal of the crosstab and other forms of linearity are not visible.

48 Almost all data points (40 out of 49) are located above the diagonal (gray field); hardly any are on (4 out of 49) or below the diagonal (5 out of 49). Within the gray field, the data points are dispersed and do not show a clear pattern.
We find the threshold pattern to be prevalent in all the variables we tested. Thus we can say that (1) more assistance coming from community members relative to outsiders, (2) the use of the community as a network, (3) the number of assistants in the project, and (4) the frequency of specific assistance activities that were provided all have an “enabling” impact on total diffusion. More problems or potential improvements might be identified and solved when more people are involved, but if the innovative idea itself is unfeasible or too difficult to realize the assistance will not have an effect on diffusion. Feedback from community members is more relevant than feedback from outsiders (as they might, for example, have a common favorite terrain or conditions in which they do their sport); this finding is similar to the idea that the most relevant information an engineer can seek out is often found within his firm (Allen 1977).

For two of the eight variables tested we also found a linear relationship with diffusion: the greater the number of assistants and the more testing conducted and feedback received, the more widely the innovation diffuses. This means that these two variables have a direct impact, as well as an enabling effect on innovation diffusion.

Two primary interpretations addressing how community assistance impacts innovation diffusion are possible. The first is that assistance by the community helps to improve the functionality and quality of the innovation and this leads to higher diffusion (assistance $\rightarrow$ quality $\rightarrow$ diffusion). The second interpretation is that the more individuals who assist in the development of the innovation, the more individuals there are who might tell others about the innovation (assistance $\rightarrow$ diffusion), thus having a positive impact on diffusion without improving quality. Due to the cross-sectional nature of the data we cannot provide direct statistical evidence indicating which path model is correct. However there are strong indicators that the first interpretation is the main effect. First, nearly 80% of the innovators were very satisfied with the assistance they received (section 2.5.3). It would seem very plausible that satisfaction is so high because the

---

49 This idea is succinctly expressed as “Given enough eyeballs all bugs are shallow” in the context of open source software development (Raymond 1999).
assistance was actually helpful in improving the innovation. In addition, it would appear unlikely that an individual who assists would promote an innovation to others that they consider to be of little use or low quality, especially since no pecuniary rewards are at stake. Further research on this issue, however, is needed⁵⁰.

These findings strongly confirm our interpretation that community supports user innovation. Not only do innovators have a stronger relationship to the community than do non-innovators and receive assistance in every case in our sample, but the relative amount of community interaction impacts the diffusion of the innovation with assistance being a necessary, but not sufficient condition for innovation diffusion.

**TABLE 2-9:**
CROSSTAB: ENCOURAGEMENT RECEIVED VS. INNOVATION PERFORMANCE (EXAMPLE)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Diffusion of Innovation (Total Diffusion)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>High</td>
</tr>
<tr>
<td>High level of encouragement received</td>
<td>1  1  1  2  2  3</td>
</tr>
<tr>
<td></td>
<td>2  1</td>
</tr>
<tr>
<td>Some support</td>
<td>1</td>
</tr>
<tr>
<td>No encouragement received</td>
<td>1</td>
</tr>
</tbody>
</table>

**Summary of crosstab:**
Position below diagonal: 5 innovations, above diagonal: 40 innovations, exactly on diagonal 4 innovations.

**Linear Regression analysis:**
Coefficients: Encouragement: B = 0.219 (0.155), not significant; Constant: B = 4.665 (0.515), p<0.001
R²=0.041, Adj. R²=0.020, F=1.988, not significant, n = 51.

⁵⁰ Note that a third interpretation that cannot be fully dismissed also exists: quality → assistance → diffusion. In such a case, an individual might actively offer his assistance if he thinks the innovative idea is very promising and of use to himself or an individual might refuse to help if he thinks the idea is hopelessly stupid or cannot be carried out at all. But it seems unlikely that such a quality screen for providing assistance exists, because data indicates that many individuals provide assistance even though they have no personal interest in using the innovation.
| Coefficients are b-values, standard error in parentheses. Constant: B = 10.330 (1.860), p > 0.001; R² = 0.436, Adj. R² = 0.297, p = 0.034, n = 40. |
|---|---|---|---|
| | 69 (18.1%) | 42 (11.0%) | 270 (70.9%) |
| n.s. | (0.157) 0.129 | 5 | 40 |
| n.s. | (0.218) 0.226 | 5 | 41 |
| n.s. | (0.029) 0.029 | 4 | 44 |
| n.s. | (0.139) 0.171 | 3 | 39 |
| p > 0.05 | (0.208) 0.213 | 8 | 26 |
| p > 0.10 | (0.106) 0.121 | 9 | 30 |
| n.s. | (0.016) 0.016 | 6 | 23 |
| n.s. | (0.106) 0.106 | 6 | 23 |

**Total**

Frequency of receiving: 0.073
Advice and suggestions for improvement: 0.022
Frequency of getting: 0.063
Regarding the problem details: 0.021
Shoring up assistance in technical assistance: 0.023
Frequency of getting feedback: 0.024
Frequency of receiving and giving assistance: 0.022
Number of individuals other serving as a network to others: 0.024
Community helped by others: 0.019
Non-assistance came: 0.022

**More General activities:**

- Cross-tab analysis
- Variance analysis
- CROSSTAB SUMMARIES: ASSISTANCE RECEIVED VS. INNOVATION DIFFUSION

**Regression Analysis**

- Not sufficient for diffusion
- Assistance necessary but diffusion is independent
- Assistance necessary but diffusion is independent
- Cross-tab: the information as non diagonal cross tab
- Below diagonal: the information as non diagonal cross tab
- Above diagonal: the information as non diagonal cross tab
Section 2.6: Findings: "Community-Based Innovation Systems"

Community members assist innovators in developing their innovations for free. In this section we report on the reasons given for this behavior. We also show that innovations are shared freely within the community, but that competition lessens both the likelihood of assistance and innovations being freely revealed.

2.6.1 Assistance is Freely Given

Community members who provided innovators with innovation-related assistance were rarely paid for their assistance and believe that community members should assist each other free of charge. In Table 2-11 we report some descriptive statistics regarding the reasons for giving assistance and present the results of a factor analysis conducted to better understand the underlying structure of the data\textsuperscript{51}.

\textsuperscript{51} We identified possible motivations for assisting by conducting exploratory qualitative interviews at the beginning of the study; we chose the eight most promising to be included in the questionnaire (Table 8). In order to better understand the structure of the relationships between these possible motivations we performed a principal component analysis. To determine the number of factors we followed the method of Horn who proposed to extract all factors that have an Eigenvalue that is higher than the highest Eigenvalue of a factor analysis of random numbers (Horn 1965). The frequently used Kaiser criterion suggests that all factors with an Eigenvalue > 1 be extracted. This is likely to overestimate the "true" number of factors (Lee and Comrey 1979; Zwick and Velicer 1986). To rule out the probability of meaningless factors we compared the Eigenvalues of our factors with the Eigenvalues drawn from a sample with random numbers (8 variables, 1000 cases). The results clearly advised us to extract two factors.
<table>
<thead>
<tr>
<th>Rank</th>
<th>Variable</th>
<th>Vareable</th>
<th>Descriptive Statistics</th>
<th>Principal Component Analysis</th>
<th>Factor I: Community</th>
<th>Factor 2: Personal</th>
<th>Agreement</th>
<th>Benefit Factor</th>
<th>T-Score</th>
<th>Mean</th>
<th>Percent Variance Explained</th>
<th>Kaiser-Normalization</th>
<th>Test of Sphericity</th>
<th>Kaiser-Meyer-Olkin</th>
<th>Bartlett's Test of Sphericity</th>
<th>Varimax Rotation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>&quot;It's my opinion that in a community, one should assist others&quot;</td>
<td>0.796</td>
<td>92.6%</td>
<td>1.18</td>
<td>1</td>
<td>78.6%</td>
<td>1</td>
<td>7.14%</td>
<td>3</td>
<td>0.785</td>
<td>2</td>
<td>74.1%</td>
<td>2</td>
<td>0.773</td>
<td>0.000</td>
<td>0.517</td>
</tr>
<tr>
<td>2</td>
<td>&quot;It's my opinion that in a community, one should assist others&quot;</td>
<td>0.782</td>
<td>78.2%</td>
<td>1.17</td>
<td>1</td>
<td>78.8%</td>
<td>1</td>
<td>7.14%</td>
<td>3</td>
<td>0.785</td>
<td>2</td>
<td>74.1%</td>
<td>2</td>
<td>0.773</td>
<td>0.000</td>
<td>0.517</td>
</tr>
<tr>
<td>3</td>
<td>&quot;I want to use the product myself&quot;</td>
<td>0.825</td>
<td>82.5%</td>
<td>1.15</td>
<td>1</td>
<td>78.8%</td>
<td>1</td>
<td>7.14%</td>
<td>3</td>
<td>0.785</td>
<td>2</td>
<td>74.1%</td>
<td>2</td>
<td>0.773</td>
<td>0.000</td>
<td>0.517</td>
</tr>
<tr>
<td>4</td>
<td>&quot;I was nice to receive recognition&quot;</td>
<td>0.557</td>
<td>55.7%</td>
<td>1.06</td>
<td>1</td>
<td>78.8%</td>
<td>1</td>
<td>7.14%</td>
<td>3</td>
<td>0.785</td>
<td>2</td>
<td>74.1%</td>
<td>2</td>
<td>0.773</td>
<td>0.000</td>
<td>0.517</td>
</tr>
<tr>
<td>5</td>
<td>&quot;I enjoy giving others advice as an expert&quot;</td>
<td>0.438</td>
<td>43.8%</td>
<td>1.05</td>
<td>1</td>
<td>78.8%</td>
<td>1</td>
<td>7.14%</td>
<td>3</td>
<td>0.785</td>
<td>2</td>
<td>74.1%</td>
<td>2</td>
<td>0.773</td>
<td>0.000</td>
<td>0.517</td>
</tr>
<tr>
<td>6</td>
<td>&quot;I was paid well for my assistance&quot;</td>
<td>0.407</td>
<td>40.7%</td>
<td>1.05</td>
<td>1</td>
<td>78.8%</td>
<td>1</td>
<td>7.14%</td>
<td>3</td>
<td>0.785</td>
<td>2</td>
<td>74.1%</td>
<td>2</td>
<td>0.773</td>
<td>0.000</td>
<td>0.517</td>
</tr>
<tr>
<td>7</td>
<td>&quot;I was nice to receive recognition&quot;</td>
<td>0.312</td>
<td>31.2%</td>
<td>1.04</td>
<td>1</td>
<td>78.8%</td>
<td>1</td>
<td>7.14%</td>
<td>3</td>
<td>0.785</td>
<td>2</td>
<td>74.1%</td>
<td>2</td>
<td>0.773</td>
<td>0.000</td>
<td>0.517</td>
</tr>
<tr>
<td>8</td>
<td>&quot;I was paid well for my assistance&quot;</td>
<td>0.097</td>
<td>9.7%</td>
<td>1</td>
<td>7</td>
<td>6.39</td>
<td>1</td>
<td>7.14%</td>
<td>3</td>
<td>0.785</td>
<td>2</td>
<td>74.1%</td>
<td>2</td>
<td>0.773</td>
<td>0.000</td>
<td>0.517</td>
</tr>
</tbody>
</table>
Community vs. Personal Benefit Oriented Motives

The variables separate into two factors. We call the first factor the “community” factor because it includes motivations and benefits that support the free sharing of assistance and information between community members. The assigned items contain the norm that assistance should be given freely (“one should assist others”, “in the community there is the norm to assist each other free of charge”) as well as the belief – related to both fairness and norms - that “if I assist others today, I will receive assistance in the future.” In addition to this, the person who assists enjoys the process of creating something jointly (“it’s fun to create something jointly”, “I enjoy giving advice”). ²²

We call the second factor the “personal benefits factor” because it contains motives that emphasize receiving extrinsic, individually-focused benefits in direct exchange for giving assistance (“It was nice to receive recognition”, “I was paid well for my assistance”) ²³. People who are highly motivated by the personal benefits factor desire payment and recognition for their work and do not want to use the product themselves: in contrast, people who scored low on the factor are likely to want to use the product themselves, are not paid well, and are not motivated by being recognized for their efforts.

The accuracy ratings (means) of the individual variables shows that respondents believe the community-factor variables to more accurately reflect their motivations for assisting than do the personal benefits variables ²⁴. Respondents view the variables related to the giving of free assistance (means of 1.48 and 2.11) and enjoying the innovation process (mean 1.79) as accurate reflections of their motivations for assisting.

²² Note that “I enjoy giving advice” receives a relatively low factor loading.

²³ Note that “It was nice to receive recognition” receives a relatively low factor loading. This might imply that, in general, the community expects its members to assist one another whenever possible and recognition for assistance beyond a simple “thank you” is not given. A reputation structure whereby those who do not assist will be singled out with a negative reputation may even exist. Thus individuals with a strong need for external rewards might only be able to satisfy this need by being paid.

²⁴ The fact that the four most important variables and the three least important ones are grouped together is rather surprising and by no means a common pattern of the method. Principal component analysis is based on correlations, not on mean differences. Thus, variables with similar patterns are grouped and not variables with similar means.
In contrast, the personal benefits variables are viewed as much less accurate. This lends support to the idea that there is more than an assessment of direct personal benefit motivating assistance-giving behavior in these communities.

The Impact of Competition on Assistance

The likelihood of giving away innovation related information may be affected by the level of rivalry within the community. If an innovator believes that revealing innovation-related information will allow a rival to outperform him, the likelihood that the innovator will reveal this information will decrease unconditionally. This hypothesis is clearly confirmed in the communities studied here: assistance is given less often in more competitive settings.

We compare the likelihood of assisting between the two less competitive communities (canyoning and sailplaning) and the two more competitive communities (boardercrossing and handicapped cycling) in our sample (Table 2-12). In the two less competitive communities, 21.7% of community members have assisted other community members on innovation projects. In the more competitive communities, only 6.7% assisted (p<0.01). This makes sense as one would not want to help a direct competitor improve his performance. In spite of this, we still observe some free assistance being given in the high rivalry communities.

\footnote{Even if we take into account that among the low competition communities more user innovations could be observed (34.7%) than in the high competition communities (19.7%) and thus the users have more opportunities to assist in a user innovation project, the difference is still striking. It can also be argued that the lower level of assistance and free sharing of important information in competitive surroundings causes these differences in innovative activities: because of less exchange there are less innovations.}
<table>
<thead>
<tr>
<th>Community</th>
<th>Percent Of Users Who Assisted Other Community Members In Innovation Project</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less Competitive (Sailplaning and Canyoning); n = 129</td>
<td>21.7</td>
</tr>
<tr>
<td>More Competitive (Boardercrossing and Handicapped Cycling); n = 62</td>
<td>6.7</td>
</tr>
<tr>
<td>Difference</td>
<td>p &lt; 0.01 (chi squared test)</td>
</tr>
</tbody>
</table>
2.6.2 The Innovation is Freely Shared in the Community

We find that fully developed innovations – like assistance – are freely shared within the community and that the likelihood of free-sharing decreases as the level of competition within the community increases.

The Innovation is Shared – Not Sold – Within the Community

We observe that once the innovation (or part of it) is developed most innovators share it with the entire community free of charge (Table 2-13) – not just with the people who assisted. Innovations are rarely sold within the community. In these communities both assistance and access to completed innovations are freely shared; the communities do not appear to operate like traditional reciprocal exchange markets.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>Median</th>
<th>High Agreement</th>
</tr>
</thead>
<tbody>
<tr>
<td>The innovation is being used by many members of community</td>
<td>4.73</td>
<td>5</td>
<td>17.6%</td>
</tr>
<tr>
<td>Share(d) innovation free of charge within the community</td>
<td>2.63</td>
<td>1</td>
<td>66.7%</td>
</tr>
<tr>
<td>Have sold the innovation to many inside the community</td>
<td>6.76</td>
<td>7</td>
<td>0.0%</td>
</tr>
</tbody>
</table>

a  7-point rating scale: 1 = very accurate; 7 = not accurate at all; n = 40.
b  Difference in means between sharing the innovation free of charge and selling the innovation is significant p < 0.001 (t-test for dependent samples).
The Impact of Competition on the Free-Sharing of the Innovation

We find that innovations are freely revealed within the community, but the likelihood of free-revealing decreases with increased levels of competition within the community. There is significantly higher agreement with the statement “I shared my innovation free of charge” in the less competitive communities (Table 2-14).

Despite lower levels of free assistance and the free revealing of innovations, the community innovation system operates even in communities characterized by high rivalry conditions. In the highly competitive communities innovations assistance is given and innovations are freely revealed – just not as often as in the less competitive communities.

<table>
<thead>
<tr>
<th>Community</th>
<th>Freely Share(d) Innovation Within the Community a</th>
<th>Have Sold the Innovation to Many Inside the Community a</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less competitive (sailplaning and canyoning)</td>
<td>2.05</td>
<td>7.00</td>
<td>p &lt; 0.05 b</td>
</tr>
<tr>
<td>more competitive (boardercrossing and handicapped cycling)</td>
<td>4.73</td>
<td>6.55</td>
<td>p &lt; 0.05 b</td>
</tr>
<tr>
<td>Difference</td>
<td>p&lt;0.001 c</td>
<td>n.s. c</td>
<td></td>
</tr>
</tbody>
</table>

a 7-point rating scale: 1 = very accurate; 7 = not accurate at all
b t-test for paired samples
c t-test for independent samples
Section 2.7: Discussion

2.7.1 Community-Based Innovation Systems: the Foundation for End-User Innovation

Studies of the innovation process often focus on firms and groups within firms. In this paper we describe an alternative form of organization that also produces valuable products: a "community-based innovation system." The community-based system provides the user-innovator with information, assistance, and links to other individuals; simply put, it provides the innovator with access to resources. In contrast, innovators in firms access such resources through the firm at large, through product development teams and other structures within firms, or through sources external to the firm. Behavioral patterns reflecting the free-revealing of assistance, information, and innovations are central to innovation in the communities we study.

We argue that this community-based innovation system works on the basis of generalized exchange. In order to understand how and why such a mechanism operates we need to better understand the reasons why community members freely provide innovation-related information and assistance and why the resulting innovations are freely revealed. Earlier in this paper (section 2.2.3), four theoretical reasons for why it might make sense to freely reveal innovation-related information were suggested (Harhoff, Henkel et al. 2000). In the remainder of this section, we discuss those reasons in light of our empirical findings and also suggest a fifth reason that appears to be overlooked in the existing literature56.

(1) To induce improvements by others: freely revealing innovations is likely to induce improvements by others because receiving assistance appears to be important in improving innovations (sections 2.5.3 and 2.5.4), thereby benefiting the innovator and the community by further advancing the sport. Innovators may be partially motivated by this intent, however those who provide assistance do not appear to be overly motivated by an interest in using or improving the resulting innovation themselves (Table 2-11). While it

56 While we cannot reject or verify these hypotheses in a statistical sense, our findings can contribute to our understanding of these potential mechanisms.
is possible that those who assist or those who simply use the innovation do make improvements that ultimately advance the sport, this appears to be a consequence of their behavior, rather than a motivating reason for their behavior.

(2)  **Setting an advantageous standard:** it is unlikely that the innovators in this sample are interested in setting a standard since they do not intend to commercialize their innovations themselves. It may be the case that some innovators are interested in using their innovations during competitive events and thus would like the innovation to be approved for use in competitions, however this motivation is most likely a rarity in the amateur communities we study.

(3)  **It makes sense to freely-reveal only in low-rivalry conditions:** we find that the level of rivalry moderates the level of revealing, but that free-revealing can be observed in both high and low rivalry conditions.

(4)  **Reputation effects and expectations of reciprocity may induce and promote free-revealing:** in this study, reputation effects do not appear to be an important factor in an individual’s decision to freely-reveal information when offering innovation-related assistance (Table 2-11). The expectation of reciprocity, on the other hand, appears to be a strong reason for why individuals freely-reveal innovation related information.

The form of reciprocity observed in these communities is of a different type than that of the two-party, “quid pro quo” form that is common in many markets. In these communities, individuals often assist innovators who they may or may not know and often assist even when not motivated by the possibility of directly using the innovation themselves or receiving anything in return. In fact, the strongest motivations for assisting - enjoyment gained from working with others, the presence of community norms supporting providing assistance for free, and the idea that helping others in the community is what should be done (Table 2-11) – are reflective of social processes not
personal benefit. These patterns suggest that generalized, rather than restricted, exchange behavior governs the exchange of information and assistance within these communities.\(^57\)

While generalized exchange is not conditional, there is an expectation that if a community member provides assistance today, someone else will provide him with assistance when he needs it. From the viewpoint of rational choice, social exchange, or evolutionary theory, the existence of generalized exchange is somewhat of a puzzle because any member of the exchange system can free-ride since there is no guarantee of reciprocity (Takahashi 2000). In order to address the free-riding issue, researchers have argued that generalized exchange stems from altruism or collective norms (Lévi-Strauss 1949; Sahlins 1972; Ekeh 1974). A recent article proposes a compelling alternative to these explanations in the form of a “fairness-based selective-giving strategy” (Takahashi 2000). In such a system, an actor offers help to those whose behaviors are in-line with the actor’s own notions of fairness.\(^58\)

In light of our empirical findings, it appears that one very important motivator for participation, contribution, and sharing in these communities is overlooked in the Harhoff, et al framework: the fun and enjoyment that arise through engagement in the task and community (Table 2-11). From this perspective, the individual does not view participation and contribution as a cost that needs to be compensated. Instead, innovation-related activities are enjoyable in and of themselves.

Community matters not only in the direct provision of resources for innovation development, but it also influences the process by which these resources are shared and

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\(^{57}\) In the context of generalized exchange, an individual receives from someone other than who they gave to originally: if A assists B, then someone other than B will generally assist A. For example, a generalized exchange explanation for why stranded motorists receive help from strangers would argue that the person who assists the stranded motorist believes that someone else will help them when they need help in a similar situation, and thus they help the stranded motorist. In restricted exchange there are only two parties in the exchange transaction and the parties transact conditionally: A only assists B, if B assists or rewards A.

\(^{58}\) The results of computer simulations show that pure generalized exchange can emerge and be maintained in a system where each actor selects a recipient whose previous behavior satisfies the actor’s own notion of fairness (Takahashi, 2000).
exchanged. Information and innovations are freely-revealed in the community-based innovation systems in our sample and we propose that this behavior is supported by a system of generalized exchange within these communities.

2.7.2 Why a Community System and Not a Market System?

Our data clearly shows that, within these sports communities, innovation related assistance and information is given for free, as are the actual innovations. These communities clearly do not operate as markets in which innovators pay for the assistance they receive – instead, a community-based system appears to be an effective form of organization within these user-communities. In this section we explain why we think this is the case and argue that a community-based innovation system seems to offer significant advantages over a market-based system.

**Difficulty in Placing a Value on Assistance and Information**

One reason a market system might lead to significant disadvantages and might even inhibit the exchange of innovation related assistance is that it may be difficult or impossible to value the information that is being shared in the context of its potential use. It is often not known if a functioning prototype will be developed, if the product will be used by even one individual, if the product will be used by many, and what the value of the product will be for those who use it. In addition, the perception of the individual who has the information and the individual who needs the information might differ. Thus, the process of finding and negotiating a price could induce prohibitive transaction costs (Bhagat, Brickley et al. 1994).

**The Effect of Intrinsic Motivation on Innovation-Related Activities**

Another reason favoring community systems over market systems in the context of the user-innovation process is related to intrinsic motivation. It has been found that if activity is rewarding in and of itself, individuals may perform the activity, as well as exchange information and assistance related to that activity, even in the absence of financial or other types of rewards (Amabile 1983; Cziksentsmihalyi 1996). Challenge and mental stimulation, control, curiosity, and fantasy are all likely to enhance an
individual's intrinsic motivation towards an activity (Malone 1987); these elements are very prevalent in innovation-related activities. On the other hand, adding a financial or other type of reward for engaging in an activity may decrease an individual's intrinsic motivation towards that activity. Such shifts in motivational orientation from intrinsic to extrinsic have been shown to negatively affect the nature of interpersonal interactions and decrease creativity (Amabile 1985; Pittman 1998). A market based on restricted exchange or external rewards might decrease the innovation-related benefits of intrinsic motivation.

**Communities Guard Against Free-Riding**

Theoretically, one major disadvantage of a voluntary community system, as compared to a market system, is that it is vulnerable to opportunism and free riding. It is argued that it pays for a person who received some important assistance in the past (and thus has a "net gain") to reject to pay his part back if he is asked to give assistance. In response, generalized exchange theorists have introduced the concepts of norms, altruism, and fairness-based selection mechanisms. (Lévi-Strauss 1949; Sahlins 1972; Ekeh 1974; Takahashi 2000). By not assisting, an individual may violate community norms and be reprimanded or penalized, and in an extreme situation be excluded from the community (Turner and Killian 1987). On the other hand, by not assisting, an individual may be viewed by others in the community as someone who does not "play fair" and thus increase his likelihood of being denied help when he needs it (Takahashi 2000).

**"Appropriation" of Rents by User-Innovators**

We show that innovating users often freely-reveal their innovations both within and outside the community, however one might wonder how the innovating-user benefits from his labor if he does not sell his innovation. The innovating users generally do not benefit financially from their innovations. In fact, it appears that they derive few benefits beyond those generated from in-house use. This pattern fits findings regarding the significant costs and low probability of success associated with efforts to protect and license intellectual property in many fields (Taylor and Silberston 1973; von Hippel 1988; Shah 2000).
Given that an innovator has chosen to freely reveal an innovation, whether or not it is considered appropriate for another party to financially profit from that innovation remains an open question. In our sample, 23.1% of innovators report that their innovation has been or is likely to be commercialized by another party, however it does not appear that the innovators will share in any profits that may be generated. We suggest that another party may be more likely to appropriate financial benefits from an innovation in fields with a weak intellectual property regime and/or in fields where the community does not mobilize against the commercializing entity. In the domain of sports-innovations, the likelihood of appropriating rents through patenting or licensing appears weak for a variety of reasons and the likelihood of the community mobilizing to protest the commercial use of a community-developed innovation is likely to be low. A strong community “voice” may affect the actions of commercializing entities acting against the spirit of these communities.

Collective Invention

In addition, users may derive many benefits from revealing (and not selling) their innovations to the community as a whole. These benefits might include psychological benefits derived from engaging in altruistic actions as well as inducing further improvements to the innovation by users as well as manufacturers – improvements that benefit the innovators as well as other users (Staub 1978; Allen 1983). This mechanism is also considered to be a driving force of the free revealing of user innovations in open source software (Raymond 1999).

Also consider the following possibility: an innovator may not be concerned about the possibility of others “free-riding” and using his innovation. This is especially true of an innovator who can not or chooses not to commercialize his innovation himself. In that case, freely-revealing would create no negative consequences for the innovator and may,

59 In contrast, the OSS community possesses both a strong “voice” and relies heavily on licenses (Raymond 1999). However, the legal validity of these licenses has yet to be tested in court.
in fact, be the most sensible behavior, since it increases the likelihood of further improvements, standardization, and adoption of the innovation\textsuperscript{60}.

2.7.3 Implications for Managers/Manufacturers

In order to obtain innovative ideas for new products von Hippel suggests adopting concepts and prototypes already developed by users (von Hippel 1986). This method, specifically designed, tested, and successful in industrial markets, has its drawbacks when applied to consumer markets with millions of users. Our findings suggest that monitoring some innovative user-communities may be an efficient method for identifying commercially appealing innovations made by users\textsuperscript{61}.

There are two critical steps in this process: selecting promising communities and gathering information from community members. Conventional wisdom would suggest picking professional, competitive communities to study. While these individuals have a need for innovations to improve their performance, professionalism often goes together with competition and we show that competition decreases the free flow of innovation information. Thus looking at highly demanding, but not necessarily competitive communities of users may make more sense; for example, a ski manufacturer is likely to be better off monitoring a community of ski fanatics in a technically and environmentally demanding region who have found ways to improve their ability to ski in such conditions rather than a group of World Cup racers. Our findings indicate that central members of the community are likely to both innovate and to have an exceptionally good knowledge of user innovations developed by other community members; thus it is not necessary to incur the high cost of contacting every community member in the process of seeking out promising innovations.

\textsuperscript{60} The authors are indebted to Carliss Baldwin, Mike Horgan, and Larry Stanley for this idea.

\textsuperscript{61} It is important to remember that the free-revealing and sharing of innovations is important in these communities. While an innovator may not mind a manufacturer producing an innovation for individuals who are unable or unwilling to build it themselves, they might object to aggressive patenting, excessive price mark-ups above cost, or not giving the innovator credit for developing the innovation if the identity of the innovator is known. More research on this area is needed.
Section 2.8: Suggestions for Future Research

This study provides four examples of “community-based innovation systems” and investigates the processes at work in these systems. In the course of this research, we uncovered many interesting puzzles and questions some of which we were able to investigate in detail and some of which we now propose as suggestions for future research.

Four sets of empirical questions stand out. Exchange Relationships: A refined understanding of the mechanisms that govern exchange relationships within these communities needs to be developed from two primary perspectives: relationships between community members (fairness, trust, generalized and reciprocal exchange) and relationships between the community and commercial entities (licensing and appropriation). Social Structures of Communities: what types of hierarchies or governance structures exist within voluntary communities? How do social and “innovation” networks develop and evolve? What is the relative importance of skill level versus pre-existing relationships in determining an individual’s position in the network, etc. Competition: In this study we look at the overall level of competition within the community, however a more nuanced understanding of the mechanisms involved would allow us to better understand the innovation process in these communities. We propose three factors that may affect the types of information and assistance likely to be exchanged under varying degrees of competition within a community: (a) assistance is likely to be given freely for innovations which do not directly affect performance and instead improve other factors such as safety, (b) even within competitive communities, there are likely to be smaller groups which are close-knit and provide assistance to one another, (c) the athletes may separate into tiers in ability and be more likely to provide assistance to those who are not close to their own ability level. Existence and Survival: The question of how these community-based user innovation systems are initiated and evolve has yet to be addressed, as does the question of what happens if the shared practices of giving free assistance and freely revealing innovations are breached.
Finally, this investigation only examines innovations by individuals who are members of voluntary communities. However, individuals outside of communities are likely to innovate as well and the process they experience has yet to be investigated. Innovators outside of communities may or may not work with the assistance of others and are likely to have different methods for finding individuals to assist them compared to innovators who belong to communities. If significant differences in process exist, it would be interesting to examine potential differences or similarities in process outcomes such as the frequency, type, quality, and diffusion of innovations; and to understand when innovators within communities more likely to and more effective in innovating than innovators outside communities (and vice versa).

Section 2.9: Conclusion

In this study we investigate the process by which innovators outside of firms who belong to voluntary user-communities obtain innovation-related resources and assistance. We examine and provide insight into the structure of four user-communities, finding that innovation-related resources, assistance, and the resulting innovations are freely and openly shared in the communities. We believe the findings of this study to be quite generalizable; but formal studies in other consumer and industrial markets are necessary and many exciting questions have yet to be addressed.
Acknowledgements

We thank Eric von Hippel for his advice and support; Carliss Baldwin, Roberto Fernandez, and Dietmar Harhoff for their insights; the students of the "Empirical Methods" course at the University of Munich for their enthusiasm and stimulating questions. Our sincere appreciation and thanks go to an anonymous reviewer at Research Policy.
Appendix: Sample Questionnaire

Below, you’ll find a shortened version of the questionnaire distributed to members of all four sports communities. The sample refers to the Boardercross community in particular.

A. Sports community

How long have you been a member of the Boardercross community? [open]; How long have you been participating in Boardercrossing? [open]; On how many days per year do you participate in this sports? [Approximately [open] days total, of which approximately [open] days are spent with the Boardercross community].

Please tell us more about your involvement with Boardercrossing community. Items: “I get together with members of the Boardercross community for activities that are not related to Boardercrossing (movies, dinner, parties, etc.”, “The Boardercross community takes my opinion into account when making decisions.” “I am a very active member of the Boardercross community.” [each 7-point rating scale]

B. Own ideas for improved or new [adaptation to specific sport] products

Have you improved existing products or had ideas for new products that were not offered on the market before? [yes/no]; Please briefly describe your product idea/improvement [open]; Please rate your product idea/improvement on the following dimensions: newness, urgency, market potential [each 7-point rating scale].

Products are often developed by individuals working together. Often one receives assistance from other people (advice, use of resources, etc). We are interested what it was like with your product idea/improvement. Items: “Talking with others about the problem that should be solved was of assistance to me.”; “Others assisted me by giving competent advice and suggestions for improvement.”; “Others assisted me by advising on technical details.”; “Others assisted me by testing and giving feedback.”; “The confirmation and encouragement of others was of help to me.” [each 7-point rating scale]

If others assisted you, we would like to know more about it. Most of the important information and assistance came from ... [7-point rating scale: community members vs. non-community members; initially close friends vs. initially strangers; experts vs. non-experts]; “Belonging to the Boardercross community helped me find people who
contributed to my product idea/improvement.” [7-point rating scale]; How many people, other than yourself, have assisted you in your product idea/improvement? [zero, 1, 2, 3-5, 5-10, more than 10]

Which statements apply to the people who assisted you with your product idea/improvement? Items: “The people who assisted me are creative and innovative themselves.”; “The people who assisted me have skills that are complementary to mine.”; “If I had a similar problem I would ask the same people again.” [each 7-point rating scale]

New product ideas/improvements often are interesting to many people. We are interested what you have done to let others know of your product idea/improvement. What have you been doing? Items: “I share(d) my product idea/improvement with the [adapted to specific community] community free of charge or at cost.” “I have sold my product idea/improvement to many members of the [adapted] community.” “I share(d) my product idea/improvement with individuals outside the [adapted] community free of charge or at cost.”; “I have sold my product idea/improvement to individuals outside the [adapted] community”, “The product idea/improvement is used by many members of the [adapted] community”, “The product idea/improvement is used by many individuals outside the [adapted] community” [each 7-point rating scale]; Has you product idea/improvement been produced for sale by a manufacturer or will it be in the foreseeable future? [yes/no]

C. Your Assistance with ideas from others (for improved or new Boardercross products)

Have you assisted another Boardercrosser who developed ideas for new or improved products (that were not offered on the market before)? [yes/no]; If yes: Please briefly describe the product idea/improvement [open]; The person who I assisted can be characterized as ... [community member or Non-Community member]

There are numerous reasons for assisting others in their projects. Why have you been assisting them? Items: “I wanted to use the product idea/improvement myself.” “If I assist others today, I will receive assistance in the future.”; “I was paid well for my assistance.”; “It was nice to receive recognition.” “It’s fun to create something jointly.”;
“It is my opinion that in a community, one should assist others.”; “In the Boardercross community there is the norm that members should assist each other free of charge.”; “I enjoy giving others advice as an expert” [each on 7-point rating scale].
CHAPTER 3

IDENTIFYING AND DISTINGUISHING BETWEEN MOTIVES:
A FRAMEWORK FOR STUDYING THE CHOICES MADE BY SOFTWARE DEVELOPERS
WHEN ALLOCATING THEIR DISCRETIONARY TIME

Abstract

This essay presents a framework to be used when studying the choices and trade-offs made by voluntary software developers when allocating their discretionary time. First, a general multi-attribute framework based on utility maximization and rational choice is presented. Then, the framework is tailored to fit the open source context. The framework captures both the complexity of motives and preferences at the individual level and the heterogeneity in this set of motives and preferences between individuals.
Section 3.1: Introduction

Software developers are voluntarily contributing their time, skill, and energy to produce new and innovative software in the cooperative environments provided by open source communities. We currently know very little about what motivates the actions of these developers and what benefits they receive from contributing to open source. Moreover, many open source developers appear to possess skills that are highly sought after in the commercial labor market. Why do these individuals choose to dedicate their time to voluntary rather than paid programming activities? In order to address this question, this paper will look at the motivations and preferences expressed by developers who engage in open source work and developers who engage in paid contract work in their discretionary time. This paper describes the framework used to guide both the collection and analysis of data.

Developing a better understanding of the motives and preferences of open source developers is of interest to management research and practice for two primary reasons. First, understanding the motives and preferences of workers can lead to the design of more effective work contracts and work environments. Second, these motives and preferences may, at least partially, guide the open source developer in his or her choice of projects and affect how he or she views and interacts with other members – including for-profit firms – of the software development community at large. Such information may be strategically useful to commercial firms deciding whether or not to enter, remain in, or exit markets where open source communities currently exist or are likely to enter.

This study seeks to identify the attributes that individual open source software developers actively trade-off in order to spend time engaged in open-source development work. However, developers are likely to be heterogeneous with respect to the number and identity of attributes that they care about. In order to capture both the complexity of

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62 To underscore the strategic importance of this topic, note that, in a famous internal memorandum now known as the Halloween Documents, managers at Microsoft Corporation argued that “Since money is often not the (primary) motivation behind open-source software, understanding of the threat posed requires a deep understanding of the process and motivation of open-source development teams.”
motives and preferences at the individual level and the heterogeneity in this set of motives and preferences between individuals, the study must be designed so that a large set of motives can appear and be distinguished from one another. In order to do this a broad framework is needed to capture all the assertions made in the academic and popular literature regarding why an individual might choose to spend his or her discretionary time doing open source software development work. Until such a framework is in place, empirical studies on developer motivation can be criticized for selection bias and misspecification.

In this paper, I present a model of developer time allocation based on utility maximization and rational choice. While the standard organizational economic characterization of choice and the classic principal-agent model in economics are based on wealth and effort alone (Holmstrom 1979; Holmstrom and Milgrom 1994; Mas-Colell, Whinston et al. 1995; Gibbons 2000; Gibbons 2001), the model presented here is in the spirit of Jensen & Meckling’s multi-attribute “Resourceful, Evaluative, Maximizing Model (REMM)” (Jensen and Meckling 1994). Several alternative forms of the set of utility function attributes in the model are examined. The model is then tailored to fit the open source context. Finally, it is argued that in a setting where complex and heterogeneous motives exist, revealed preference alone is not an adequate tool for understanding the choices made by individuals; data drawn from interviews and surveys must be used as well\(^3\).

Section 3.2: A Model of Developer Choice

3.2.1 Utility Maximization & Rational Choice

I adopt a framework of utility maximization, based on the rational choice axioms. The hypothesis of rationality is embodied in two basic assumptions about the preference relation, \(\succ\): completeness and transitivity (Mas-Colell, Whinston et al. 1995, pg. 6-7).

\(^3\) Ethnographic methods (providing highly detailed information on small and select groups of participants) and analysis of website content and on-line exchanges and behaviors are also likely to be useful. No matter what data collection methods are used, care must be taken when generalizing individual or community specific findings to larger populations.
(a) Completeness: for all \( x, y \in X \), we have that \( x \succ y \) or \( y \succ x \) (or both)

(b) Transitivity: for all \( x, y, z \in X \), if \( x \succ y \) and \( y \succ z \), then \( x \succ z \)

An individual’s preferences may fail to satisfy the transitivity property for a number of reasons including “just perceptible differences” between items; framing problems in which the manner in which things are presented can influence preference ordering; and changes in tastes (Mas-Colell, Whinston et al. 1995, pg. 7-8). In addition, group decision processes based on rational (and thus transitive) preferences do not always result in a transitive ordering. One such example is the Condorcet paradox (Mas-Colell, Whinston et al. 1995, pg. 8).

My focus is on individual motivation. I assume that individuals are able to order their preferences and that these preferences are transitive. Thus, this study will not examine cognitive biases in decision-making due to framing problems (Kahneman and Tversky 1984). Also, I will assume that differences between items are perceptible to the individual. The issue of changes in tastes will be indirectly addressed by controlling for the amount of time a developer has been involved in open source and the developer’s role in the community: increased participation in open source projects may lead an individual to value attributes of the open source environment or make the individual more likely to take on various roles within the community. Because the focus of this study is on individual motivation, group decision processes that may result in a non-transitive ordering of individual preferences will not be addressed.

In what follows, individual preferences regarding wealth, effort, and all other elements in the utility function will be defined to be rational - and therefore both complete and transitive - as discussed above, monotone (and therefore locally non-satiated), convex (meaning there are diminishing rates of marginal substitution), and continuous within defined limits.
(c) Monotone: the preference relation $\succ$ on $X$ is monotone if $x \in X$ and $y \succ x$ implies $y \succ x$ (Mas-Colell, Whinston et al. 1995, pg. 42-3).

i. If $\succ$ is monotone, then it is locally non-satiated.

ii. The preference relation $\succ$ on $X$ is locally non-satiated if for every $x \in X$ and every $\varepsilon > 0$, there is $y \in X$ such that $|y-x| \leq \varepsilon$ and $y \succ x$.

(d) Convex: the preference relation $\succ$ on $X$ is convex if for every $x \in X$ the upper contour set $\{y \in X: y \succ x\}$ is convex. That is if $y \succ x$ and $z \succ x$, then $\alpha y + (1-\alpha)z \succ x$ for any $[0,1]$ (Mas-Colell, Whinston et al. 1995, pg. 44).

(e) Continuous: the preference relation $\succ$ on $X$ is continuous if it is preserved under limits. That is, for any sequence of pairs $\{(x^n, y^n)\}_{n=1}^{\infty}$ with $x^n \succ y^n$ for all $n$, $x = \lim_{n \to \infty} x^n$ and $y = \lim_{n \to \infty} y^n$, we have $x \succ y$ (Mas-Colell, Whinston et al. 1995, pg. 46).

3.2.2 A Multi-Attribute Model of Choice

One of the main questions this study seeks to answer is what motivates the many individual software developers who belong to open source development communities. The standard utility function of organizational economics and principal-agent models suggests that individuals take two primary dimensions of preference, wealth and effort, into account (Ross 1973; Holmstrom 1979; Mas-Colell, Whinston et al. 1995):

**Two Attribute Model:** $u(\cdot) \equiv u(w,e)$

where $w$ represents wealth and $e$ represent effort, $\partial u/\partial w > 0$ and $\partial u/\partial e < 0$, and $w$ and $e$ are complete, transitive, monotone, convex, and continuous by definition.

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64 The agent’s risk preference is often also considered (Mas-Colell, Whinston et al. 1995; Gibbons 2001).
Wealth in this framework is generally taken to be monetary income (Jensen and Meckling 1994, reprinted in Jensen 1998, pg. 22-23), derived from employment or other wage-earning activity. It is generally either assumed that the individual cares for nothing besides monetary income or that all goods that an individual cares about can be bought and are thus subsumed in w. Thus this framework a priori excludes the possibility that, for some individuals, there are valued things that money cannot buy.

Effort in this framework is a one- or multi-dimensional measure of how “hard” an individual works (Mas-Colell, Whinston et al. 1995, pg. 479). Clearly, it is extremely difficult to gauge how “hard” someone is working and this conception of effort, while theoretically useful, is difficult to measure empirically. Part of the problem is that this standard notion of effort combines two aspects into one measure: the amount of time spent working and the individual’s perception of the pleasantness or unpleasantness of the work activity.

In contrast to the two-dimensional economic model, the Resourceful, Evaluative, Maximizing Model (REMM) of individual behavior proposed by Jensen and Meckling is multi-dimensional: “The individual cares about almost everything: knowledge, independence, the plight of others, the environment, honor, interpersonal relationships, status, peer approval, group norms, culture, wealth, rules of conduct, the weather, music, art, and so on (Jensen and Meckling 1994, reprinted in Jensen 1998, pg. 13).”

For example, imagine a software developer who must decide how she will spend the 24 hours that make up each day. Suppose she has a task at work that she must finish today. She can either do the work in a relatively mundane, but straightforward manner in

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65 The number of dimensions taken into account in an individual’s utility function differs by field: while the organizational economics and classic agency models take only two-dimensions into account, consumer theory includes many additional dimensions to represent choices made when evaluating different baskets of goods and financial models often add dimensions of time. The wealth and effort model is valued in many settings for its simplicity. However, in this context, the inherent simplicity of the model limits our investigation and understanding: the vast majority of open source developers are not engaging in this activity for direct financial benefit, however they are putting forth effort: what justifies this effort?
10 hours while listening to music and chatting with coworkers; or she can do the work in a more challenging way in 8 hours, but will have to focus completely on the work. If she works 8 hours, she will have 2 hours after work to play volleyball (her favorite hobby) before going home. We can see that the developer is motivated by both obtained attributes such as possible reputation and learning obtained by completing the task on time and experiential attributes such as engaging in a fun and challenging activity, listening to music, playing volleyball, etc. Obtained attributes accrue over time and do not have to be consumed while engaged in a task. In contrast, experiential attributes are acquired and consumed while engaged in a task; they influence an individual's perception of the pleasantness or unpleasantness of the activity.

The software developer's preferences can be represented using a multi-attribute model of behavior that accounts for both obtained and experiential attributes. Formally, I will represent the multi-attribute model as follows:

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66 Example: Having friends is an obtained attribute, while experiencing social interactions is an experiential attribute.

67 The idea that such experiential attributes exist and impact individual utility is supported by research in organizational theory, psychology, and social psychology – as well as everyday observation. Both job characteristics theory and Cziksentmihalyi's psychological work on creativity and flow indicate that some task-specific characteristics affect outcomes such as individual motivation, job satisfaction, work performance, and absenteeism. Some of the task characteristics specified in these studies fall under the category of what we call "experiential attributes." Job characteristics theory focuses on identifying and building into jobs those characteristics that create conditions for high work motivation, satisfaction, and performance. Turner and Lawrence's study of the impact of several objective task attributes on job satisfaction and absenteeism provided the foundation for this stream of research (Turner and Lawrence 1965). Among the task attributes studied were task variety, autonomy, necessary and optional interactions with others, knowledge and skills required, and responsibility entrusted to the jobholder (this study led to the creation of the Requisite Task Attribute measure). Turner and Lawrence found evidence in support of their hypothesis – that higher levels of "good" attributes such as those listed above increased employee satisfaction and reduced absenteeism - and they also found that employees with different subcultural backgrounds reacted differently to these attributes. Hackman and Lawler reduced the number of job characteristics to four and suggested that the relationship between these and motivation were moderated by the need for personal growth and by commitment to the job (Hackman and Oldham 1980). Their study eventually led to the Yale Job Inventory and inaugurated and fostered the use of self-report survey methods in job analysis. Along these lines, Hackman and Oldham's five-factor model identifies five reasonably objective, measurable, and changeable properties of work tasks (some of which are experiential attributes) that foster three critical psychological states. These three critical psychological states, moderated by three additional variables, affect an individual's motivation, work effectiveness, and level of satisfaction (Hackman and Oldham 1980, Chapter 4). This study led to the Job Diagnostic Survey, which is still an important job evaluation instrument today.
**Multi-Attribute Model:** \( u(\cdot) \equiv u(w, x_1, \ldots, x_n, y_1, \ldots, y_m, t) \)

Here \( w \) represents the standard conception of wealth as monetary income; \( x_1 \ldots x_n \) represent attributes that money cannot buy; \( y_1 \ldots y_m \) are experiential attributes of a task and come from the deconstruction of effort into its constituent components; and \( t \) is the time spent on the task. I assume all \( x \)'s and \( y \)'s are \( \geq 0 \), \( \partial u/\partial x_i < 0 \) and \( \partial u/\partial y_i < 0 \). All \( x \)'s and \( y \)'s are complete, transitive, monotone, convex, and continuous by definition.

The model consists of a single-period utility function with stocks (obtained attributes) represented by \( w \) and the \( x \)'s, and intra-period flows (experiential attributes) represented by the \( y \)'s and \( t \); this is parallel to the construction of the 2-attribute model where the individual receives \( w \) at the end of the period and \( e \) is an intra-period flow.

In this model, the individual chooses how to allocate his time between activities. Different activities have different sets of attributes that provide the individual with utility. We might imagine that an individual first computes (or perhaps more realistically, "gets a feel for") the highest utility that he or she could realistically achieve under various scenarios, based on the technological constraints he or she faces. The individual then chooses among these sets, picking the set that provides him or her with the highest level of utility. If the individual faces no technological constraints, he or she can assemble the set of activities that provides him or her with the highest utility.

**Obtained Attributes (x's)**

Obtained attributes accrue over time as an individual engages in a task and do not have to be consumed while engaged in a task; they can be thought of as stock variables. Wealth is one of many obtained attributes that a developer might value and is represented in the model by "\( w \)"; monetary income. Items which money can buy are subsumed in "\( w \)". The "\( x \)'s" of the model represent obtained attributes other than wealth; these things cannot be bought with money. Obtained attributes that may be particularly important to the software developer include reputation, wealth, status, achievement, propagating the ideology of free software, and knowledge. In general, obtained attributes can be
accumulated over time and held on to, but they can also be "used up" or left to decay – for example, wealth can be spent and status within a group can improve or decline.

**Experiential Attributes (y's)**

As noted previously, there is an ambiguity in the basic models of effort used in economic theory (Mas-Colell, Whinston et al. 1995, pg. 479), because effort contains both the amount of time spent on a task and the individual’s perception of the pleasantness or unpleasantness of the task. Because of this ambiguity, effort, as defined, cannot be objectively measured. It is a requirement of this study’s empirical strategy to establish a reasonable method for estimating effort. This will be accomplished by deconstructing effort into its component parts.

The overall effort required for a task or activity may be thought of as the time an individual spends on a task plus the utility and disutility that arises from an individual's engagement in a task through various experiential attributes. Both of these elements are unquestionably recognized as components of effort. Experiential attributes are acquired and consumed while engaged in a task; they influence an individual’s perception of the pleasantness or unpleasantness of the activity and thereby contribute to the task’s overall utility (or disutility). They can be thought of as flow variables.

By separating the measurement of time, "t", from the measurement of the experiential attributes, "y's", an individual associates with a task, the time component of effort is normalized and becomes comparable across individuals. In this framework, the variable $t_e$ denotes the amount of time spent on task $z$ (in contrast with the more common use of $t$ to describe running time that will not be used here). Measuring time spent on different tasks will be critical to this study. The challenges of measuring time spent are discussed in the methods chapter.

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68 In this way, the time allocated to a task can be thought of as effort stripped of all its experiential attributes. Positively valued experiential attributes might be thought of as decreasing the overall effort involved and negatively valued experiential attributes as increasing the overall effort involved.
Others have suggested that developers value experiential attributes, such as fun, flow, social interactions, the ability to easily share information with others, and a variety of other experiential attributes related to the work environment (Weizenbaum 1976; Cziksentmihalyi 1996; Torvalds 1998). Examples of experiential work environment attributes include the extent to which one is micro-managed, discretion over how one does one’s work, sharing of information and tips between colleagues, etc. Individual-level data can be collected on the experiential attributes that influence the choices a developer makes.

3.2.3 Alternative Forms of the Multi-Attribute Utility Function

In this framework, the mix of attributes in the multi-attribute utility function can take many forms. Three specifications are of particular interest because they correspond to qualitatively different patterns of human motivation and behavior. The first specification is the null, which is based only on wealth and time:

Null: \( u(\cdot) \equiv u(w, t) \)

In alternative 1, every individual has a single dominant motive in addition to wealth and time spent.

Alternative 1: \( u(\cdot) \equiv u(w, x_m, t) \) or \( u(w, y_m, t) \)

Alternative 2 is similar to alternative 1, but it allows for the possibility that individuals may be heterogeneous with respect to the identity of the third dominant motive.

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69 Clearly different organizations and groups within organizations differ on these types of attributes and an individual may be able – to a degree – attempt to find a group or organization that fits her ideals. However, an individual will likely find some things about each group that she likes and some things that she doesn’t like – and generally does not have the ability to vary individual attributes in the work environment.

70 While only a single motivation in addition to wealth and effort is included here, it could be that more than one additional motive be present. The point is that in this alternative the individual has only a very small number of attributes that he trades-off.
**Alternative 2:** \( u(\cdot) \equiv u(w, x_1, t) \)
\[ \equiv u(w, x_2, t) \]
\[ \equiv u(w, y_5, t) \]
\[ \equiv u(w, y_m, t) \]
\[ \text{etc.} \]

In alternative 3, each individual has a complex set of motives, meaning that he has many attributes to consider and trade-off in his utility function. Each individual in the population possesses the same set of motives.

**Alternative 3:** \( u(\cdot) \equiv u(w, x_1, \ldots x_n, y_1, \ldots y_m, t) \)

Alternative 4 is similar to alternative 3, but it allows for the possibility that each individual may be heterogeneous with respect to the attributes that comprise her complex set of motives:

**Alternative 4:** \( u(\cdot) \equiv u(w, x_1, \ldots x_n, y_1, \ldots y_m, t) \)
\[ \equiv u(w, x_1, x_2, x_8, y_1, y_3, y_{12}, t) \]
\[ \equiv u(w, x_1, y_1, y_2, y_5, y_7, y_m, t) \]
\[ \equiv u(w, x_1, x_2, x_3, x_4, x_5, x_n, t) \]
\[ \text{etc} \]

There is a strong possibility that each of the five forms above is represented within a population. By studying many individuals within a population, it can be determined whether the population consists of individuals focused on wealth and time alone, homogeneous individuals with only a few dominant motives, heterogeneous individuals with only a few dominant motives, heterogeneous individuals with complex sets of motives, or combinations of these groups.
Relevance to the Open Source Context

The existing literature on open source discusses a variety of attributes that may be important to the developer and suggests that different developers might value attributes differently. Four attributes often discussed are reputation within a specific open source community (status), learning, career concerns, and having fun (an intrinsic reward). For example, Eric Raymond, a participant-observer in the open source community argues that:

"Good reputation among one's peers is a primary reward. We're wired to experience it that way for evolutionary reasons touched on earlier (Raymond 1999, pg. 84)."

Lakhani and von Hippel survey individuals who provide and use help-line-like product support on one open source community and find that

"Information providers do this primarily in order to learn, rather than to answer questions (Lakhani and Hippel 2000)."

Lerner and Tirole focus on career concerns as the primary motivator for engaging in open source work (Lerner and Tirole 2002). Linus Torvalds, an important figure in the open source world and author of the Linux core, stresses the importance of fun:

"Most of the good programmers do programming not because they expect to get paid or get adulation by the public, but because it is fun to program (Torvalds 1998)."

Individual motives for open source participation appear to be highly heterogeneous.

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Note that many other motivations are discussed in the literature and the four examples included here are illustrative only. There is a great deal of speculation regarding the motives of open source developers, interested readers can start at www.slashdot.org, www.firstmonday.org, www.tuxedo.org/est/writings/.
Torvalds and Raymond also tell us that different developers are driven by different motives:

“All members agree that open source is a good thing and worthy of significant collective effort... However, the reasons individuals and various subcultures give for this belief vary considerably (Raymond 1999, pg. 67).”

“...it is very subjective, depending from person to person, how much programming people are willing to do just for “fun.” The very best programmers may indeed be willing to do all their work for “fun”... providing they don’t starve, of course. But I’d expect that as you go beyond the apex of the pyramid, programmers want more and more of their work to receive some sort of “quid pro quo” – reputation, even distribution of contributions among user-developers, “taking out” for their “putting in” – with a base of programmers at the bottom working just for money (Torvalds 1998).”

Thus it is plausible that an open source developer may be getting one, some, many, or all of a variety of attributes and that his tastes for attributes may differ considerably from those of others. The multi-attribute rational choice framework allows these observations to present themselves in the data, and thus does not a priori limit our understanding of a rich and complex phenomenon. This framework allows a variety of complex and heterogeneous motives and preferences to reveal themselves.

3.2.4. Possibilities Open to the Individual

One of the constraints faced by our volleyball-playing software developer is that she has only 24-hours in a day to spend. The various bundles of attributes achievable by expending a fixed amount of time define the individual’s possibilities frontier. The individual has some knowledge of what possibilities frontiers are available and what he
can achieve by spending a given amount of time; however, this knowledge is likely to be incomplete in the sense that the individual may not know that certain attributes are available to him if he engages in a certain activity. In addition, the individual's knowledge of possibilities may be imprecise in the sense that an individual may over or underestimate what he can achieve or cognitive biases may affect his decision-making (Strotz 1956; Kahneman and Tversky 1984; Camerer 1995).

Possibilities frontiers may be different for different individuals, depending on what they can "make of" a given situation. Education, skills, creativity, etc. are likely to be factors here: for example, an individual lacking prior experience and/or a specific type and amount of education may be cut off from some activities and the attribute bundles associated with those activities. Individual behavioral traits may also play a role in defining the opportunities available to an individual.

The possibilities frontiers open to an individual as a function of time spent can be represented as a set of graphs. Chart 3-1 provides an example. The subscript on t denotes the number of hours in a day the individual chooses to be active. In this example the individual can attain more of both attributes a and b as they increase the amount of time spent between t_0 and t_12; more of attribute b, but less of attribute a between t_12 and t_13; and less of both attributes between t_13 and t_14. To fix ideas, imagine that a is the level of respect the developer is awarded by others in his peer group and that b is the amount of fun the developer has while programming. If the developer spends up to 12 hours on the activity, he receives respect for being perceived by others as dedicated, beyond 12 hours others begin to perceive him as inefficient and perhaps only "1-dimensional" (in that he appears to have few other interests) and they begin to afford him less respect. The individual can program for up to 13 hours and have fun; after 13 hours the activity is not fun anymore since he is tired, his eyes are strained, etc. This unpleasantness or "lack of

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72 For example, Bowles, Gintis, and Osborne argue that unexplained variance in the standard earnings function is due in part to individual differences in behavioral traits that are rewarded on labor markets, and not captured by the usual measures of schooling, work experience, parental economic status, and cognitive performance (Bowles, Gintis et al. 2001). They suggest that incentive-enhancing preferences – individual traits that are valued by employers such as such as truth-telling – affect individuals’ job placements and income.
fun” takes away from the amount of fun he experienced in the first 13 hours of the activity.

**CHART 3-1: POSSIBILITIES FRONTIER**

![Chart showing possibilities frontier]

Let the subscript on t denote the number of hours in a day the individual chooses to be active. As the individual is active for more hours, the frontier generally moves out and then begins to retract. In this example the individual can attain more of both attributes between $t_9$ and $t_{12}$; more of attribute B, but less of attribute A between $t_{12}$ and $t_{13}$; and less of both attributes between $t_{13}$ and $t_{14}$. $t_{13} < t_{max} < t_{14}$
An individual has only so much time to allocate, being limited by the number of hours in a day and by physiology. There’s an amount of time, \( t_{\text{max}} \), less than 24 hours up to which better bundles can be obtained. As the time spent increases at all points below \( t_{\text{max}} \), the frontier moves out so that the individual can obtain (at least some) more highly preferred bundles of attributes. Spending amounts of time greater than \( t_{\text{max}} \) will cause the possibilities frontier to retract with respect to all attributes\(^{73}\). In Chart 3-1, \( t_{\text{max}} \) is somewhere between 13 and 14 hours.

We know that (1) a possibilities frontier exists for every amount of time that can be invested and (2) spending more time, up to \( t_{\text{max}} \), will bring the individual at least as much of an attribute as she would have received if she spent less time. What is not known (to the researcher) is the relationship between attributes as more time is spent (i.e. doubling time spent may result in doubling the levels of all attributes, increase all attribute levels by 10%, or triple some attributes and leave others unchanged, etc.).

In addition the values of some attributes may only move in a specific range, be constant in certain ranges, may move in steps, have non-linear relationships with other attributes, etc. Thus we do not know the precise shape of each possibilities frontier or how the possibilities frontier for a given amount of time compares to the frontier for a different amount of time, except that better bundles are achievable with greater investments of time to \( t_{\text{max}} \).

**Choosing Between Bundles**

Given knowledge of the possible attribute bundles that exist, a rational individual will choose to allocate her time by maximizing her utility (Mas-Colell, Whinston et al. 1995, pg. 314). In making that choice, the individual must take \( n+m+3 \) dimensions into account\(^{74}\). For a given \( t \), let the set of attributes that maximizes her utility be called

\(^{73}\) The point of diminishing value may differ across elements of the preference space.

\(^{74}\) These dimensions account for wealth, time, \( n+m \) attributes, and the value of utility. The solution space has \( R^{n+m+1} \) dimensions. Time spent, as the individual chooses between available bundles, is fixed and utility is a function of these choices. Physical limits in collecting and cognitive limits in processing such information are likely to influence the choice-making process, however we will assume that the
\( \hat{z} \equiv (\hat{w}, \hat{x}_1, \ldots, \hat{x}_n, \hat{y}_1, \ldots, \hat{y}_m; \hat{t}). \) \( \hat{z} \) is a vector defined as the point of tangency between the possibilities frontier and the highest utility isoquant achievable. \( \hat{z} \in \mathbb{R}^{n+m+1}. \) By construction, there exists a single \( \hat{z} \) corresponding to every allocation of time, \( t. \) This relationship is illustrated in Chart 3-2. Therefore, the functions \( \hat{z}(t) \) and \( u(\hat{z}(t), t) \) exist. Note that \( \hat{z}(t) \) returns a vector and \( u(\hat{z}(t), t) \) returns a scalar\(^75\).

**CHART 3-2: THE SET OF PREFERRED BUNDLES**

The point of tangency between a possibilities frontier associated with a given amount of time and a utility isoquant defines the preferred bundle of attributes, \( \hat{z} \), given an allocation of time, \( t. \) This example shows how there is a unique bundle preferred by the individual, \( \hat{z} \), for every given allocation of time. The set of preferred bundles constitute the function \( \hat{z}(t) \). The indifference curve and possibilities frontier tangent at \( \hat{z}_{11} \) are highlighted.

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\(^{75}\) \( \hat{z}(t) \) takes time, a one-dimensional, continuous variable and returns a \( n+m+a \)-dimensional attribute bundle \( (\mathbb{R}^1 \rightarrow \mathbb{R}^{n+m+1}). \) \( u(\hat{z}(t), t) \) takes \( n+m+2 \) dimensions into account and returns a utility value \( (\mathbb{R}^{n+m+2} \rightarrow \mathbb{R}). \)
There exists an amount of money, \( W \), such that the utility derived from allocating time \( \hat{t} \) and receiving only \( W \) is equal to the utility from allocating \( \hat{t} \) and choosing the most preferred bundle of attributes: \( u(W, \hat{t}) = u(\hat{w}, \hat{x}_1 \ldots \hat{x}_n, \hat{y}_1 \ldots \hat{y}_m, \hat{t}) \). The \( V \) operator provides a mapping from the preferred set of attributes to the amount of money alone that would give an individual the same "feeling of satisfaction" (utility) with the same investment in time: \( V: \hat{z}(t) \rightarrow W \).

\( V \) returns the "dollar equivalent" of the optimal consumption bundle, \( \hat{z} \), generated by a particular allocation of time. Theoretically, such a mapping exists for all \( \hat{z} \), because - under the assumptions of completeness, transitivity, monotonicity, convexity, and continuity - the rational individual "is always willing to give up some sufficiently small amount of any particular good (oranges, water, air, housing, honesty, or safety) for some sufficiently large quantity of other goods. Furthermore, valuation is relative in the sense that the value of a unit of any particular good decreases as the individual enjoys more of it relative to other goods" (Jensen and Meckling 1994, reprinted in Jensen 1998, pg. 13).\(^76\)

This idea is illustrated in Chart 3-3. The individual is choosing between many bundles composed of many obtained and experiential attributes (only two of these attributes are shown on the chart). For example, think of attribute \( a \) as an obtained attribute such as reputation and attribute \( b \) as an experiential attribute such as fun. Given time \( \hat{t}_{11} \), the individual chooses bundle \( \hat{z}_{11} \). The value of this bundle expressed in monetary terms alone is \( W_{11} \). In other words, the individual would get the same "feeling of satisfaction" if the bundle of attributes, \( \hat{z}_{11} \), was replaced with \( W_{11} \). However, knowing \( \hat{z}_{11} \) alone does not tell us the value of \( W_{11} \). To know \( W_{11} \) we would need to know the functional form of the indifference curve or the mapping operator \( V \). Nevertheless, \( W \) most likely exists.

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\(^76\) One might argue that \( W_{oa} \) may not even exist for some programmers, implying that no amount of money combined with the attributes associated with contract work would convince them to engage in contract work when the option to do open source work was available. In reality this is unlikely to be the case for most developers.
CHART 3-3: 
DETERMINING THE MONETARY EQUIVALENT OF A BUNDLE

\[ \hat{z}_{11} \equiv (\hat{\omega}, \hat{a}, \hat{x}_2, \ldots \hat{x}_n; \hat{b}, \hat{y}_2, \ldots \hat{y}_m; \hat{t}_{11}) \]

Possibilities frontier given time allocated \( \hat{t}_{11} \)

Given time allocation \( \hat{t}_{11} \), the individual chooses the bundle that maximizes her utility:
\[ \hat{z}_{11} \equiv (\hat{\omega}, \hat{a}, \hat{x}_2, \ldots \hat{x}_n; \hat{b}, \hat{y}_2, \ldots \hat{y}_m; \hat{t}_{11}) \].

The value of this bundle expressed in monetary terms alone is \( W_{11} \): \( V(u(\hat{z}_{11}; \hat{t}_{11})) \equiv W_{11} \). However, we must know both \( \hat{z}_{11} \) and the functional form of the utility curve to know the value of \( W_{11} \).

We know little about the functions \( u(\hat{z}(t)) \) and \( u(\hat{z}(t), t) \) and the mapping \( V: \hat{z}(t) \rightarrow W \) beyond the fact that they exist. Because the utility function (and the individual's utility isoquant) is not known, the bundle \( \hat{z} \) is not known and therefore \( u(\hat{z}(t)) \) and \( u(\hat{z}(t), t) \) are also not known\(^{77}\). \( V \) is a mapping and is continuous, however its form is (1) not known and (2) not discoverable because it includes bundles that will not be chosen (in equilibrium). Even if \( \hat{z}(t) \) were known, the mapping \( V: \hat{z}(t) \rightarrow W \) might not be an

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\(^{77}\) In addition, the possibilities frontier can only be approximated because at any point in time the individual knows only so much about the possibilities that exist and those that he could create — and getting such information from any individual poses difficulties.
invertible because it might not be a function, i.e. a number of different attribute bundles might generate the same utility and hence the same wealth equivalence \( W \).

This idea is illustrated in Chart 3-4. The form of the utility function taking wealth, time, and all \( x \) and \( y \) attributes into account - \( u(\hat{z}(t), t) \) - is not known. The function may not be monotonic; in Chart 3-4 we can see that the dotted horizontal line intersects four different bundles. Thus the mapping \( V \) would not be invertible. The function may also have more than one global peak. In this example, there are two global peaks.

**CHART 3-4:**
**DIFFERENT BUNDLES MIGHT GENERATE THE SAME UTILITY LEVEL**

The shape of the utility function taking wealth and all \( x \) and \( y \) attributes into account is not known. The function may not be monotonic. One or more bundles might generate the same utility level and wealth equivalent, \( W \). In this example, four bundles generate the same utility. The function may also have more than one global peak. In this example, there are two global peaks.
Section 3.3: The Limits of Revealed Preference as an Empirical Strategy in the Context of Open Source

In this section, the multi-attribute framework is tailored to fit the open source context and, given this framework, the requirements of an empirical strategy for gathering data on individual motivations and preferences are discussed. First, three assumptions are made regarding the behavior and work context of software developers in order to fit the multi-attribute utility framework to the context of open source work, in the presence of a contract programming alternative. Then a formal argument showing exactly what can and cannot be learned about individual preferences and motivations through the use of revealed preference is presented. I conclude that, in a setting where complex and heterogeneous motives exist, revealed preference alone is not an adequate tool for understanding the choices made by individuals. Interviews and surveys must be used as complements to the preferences revealed by actions.\(^78\)

3.3.1 Specializing the Multi-Attribute Model to Fit the Open Source Context

Assumption 1: Developers allocate their discretionary time according to utility

Discretionary time for software developers can be thought of as time not devoted to work directly related to their primary source of income and employment (hereafter referred to as the developer’s “day job”). Discretionary time may consist of time outside of day job hours during the workweek or on weekends or extra time while at one’s day job. Developers may allocate this time to one or more of a wide array of activities: family, hobbies, volunteer work, watching television, open source work, contract software development work, etc.\(^79\)

The focus of this work is discretionary time allocated to software development work, either as open source work or contract development work by developers who also

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\(^{78}\) Moreover, the number of options are few relative the number of potentially important preferences and motives.

\(^{79}\) Metaphorically, discretionary time for software developers is dubbed the “back-40”: the 40 hours per 5-day workweek that are not accounted for once 8 hours/day are allocated to working and 8 hours/day are allocated to sleeping (Gabriel 2001).
have day jobs\textsuperscript{80}. The goal of the study is to understand the software development related motives and preferences of developers \textit{within} each of these groups – i.e. to identify the attributes that they value. It is possible that open source developers and contract developers place value on very different attributes or that they place value similar attributes in similar ways, but differ on another dimension, such as overall wealth or contracts with primary employers\textsuperscript{81}. By comparing \textit{between} these two groups, a very clear comparison can be made: given that a developer has free time that she devotes to programming, why would she make the choice to volunteer her time and skill rather than program for money?

\textit{Assumption 2: The Utility Function is Separable and Additive}

There is an implicit assumption here that the utilities gained from the day job and from the use of free time are separable and additive, that is: \( u_{\text{dayjob}}(\ldots) + u_{\text{free-time}}(\ldots) = u_{\text{total}} \). Note that the individual’s real decision involves maximizing her \textit{overall} utility - the utility from her day job plus contract work or the utility from her day job plus open source work. An individual may make the open source vs. contract work decision based not only on the attributes generated by each of these options, but also based on how they combine with the attributes available at her day job. It is only because we assume that the utilities from the day job and work done during discretionary time are additive and separable that we can think of the developer’s task as maximizing the overall utility she gets outside of her day job\textsuperscript{82}.

\textsuperscript{80} Some developers also do individual programming work for themselves as a hobby or to satisfy their own needs. Some developers choose to rely on contract work as their primary source of income. Note that contract work is substantially different from full-time employment in many ways (Kunda, Barley et al. 2002).

\textsuperscript{81} Or that the distribution of open source developers based on what attributes they value is very different from the distribution for contract programmers.

\textsuperscript{82} If the utilities are not separable and additive in the sense that interaction effects between the amount of the attribute derived from the day job and additional work, this equation (and the framework overall) becomes much more complicated. We assume, \( u_{\text{dayjob}}(\ldots) + u_{\text{free-time}}(\ldots) = u_{\text{total}} \). Instead, it could be that \( u(w+w_{\text{dayjob}}, x_1+x_{\text{dayjob}}, x_2+x_{\text{dayjob}}, x_3+x_{\text{dayjob}}, \ldots, x_n+x_{\text{dayjob}}, t+t_{\text{dayjob}}) = u_{\text{total}} \) where the unsubscripted variables could be obtained from accepting the firm’s offer, open source work, or other contract work.
Assumption 3: Programming for Money is One Way to Spend Discretionary Time

The demand for Java developers has exceeded the supply in recent years. "The IT staffing industry is no longer a back room, administrative function. With demand far exceeding supply, the entire industry needs to focus on talent management as its core value adding function (Grantham 2001)." Despite paying between 10 and 20 percent more for IT staff than for non-IT staff - companies are still having trouble finding IT professionals with Java skills according to a Meta Group survey of 500 large US companies (New Work Media 2001). Thus, it is assumed that developers can find part-time or contract work to do in their discretionary time, if they choose to do so.

Note that the study design will be alert to the idea that some open source developers may do all or most of their open source programming during day job hours (and that it may not be appropriate to do contract work during day job hours) and that some minimum amount of discretionary time may be needed to engage in paid contract work.

Choosing Between Open Source and Contract Work

Because of Assumption 3, we know that a developer has the choice of allocating his discretionary time to a wide variety of other activities. Here we focus on developers who choose to spend their discretionary time programming, under contract for money or on an open source project. These choices are described and compared below.

Under the contract alternative, the developer receives monetary income and must spend time on the contract work; the values of the other attributes will change to reflect the obtained and experiential attributes of the task.

Contract ("earn money") choice: $u(w_c, x_{1c}, \ldots, x_{nc}, y_{1c}, \ldots, y_{mc}, t_c)$

where $w_c > 0$ and $t_c > 0$, and the values of all other attributes are $\geq 0$. The variables that can be directly observed, time spent and wages received, are set off in bold in this expression.
To simplify the exposition, I benchmark the values of the x and y attributes at zero:

**Benchmarked contract choice:** \( u(w_e, 0, \ldots, 0, t_c) \)

The developer also has the option of joining and contributing to an open source community. To simplify this exposition, we will assume that the developer's time spent increases to the same level as in the contract choice, but that the developer's incremental earnings are zero. All other attributes may increase in value, remain constant, or decline as compared to their values in the contract option. Again, to simplify the exposition, the values of the x and y attributes are measured relative to their values in the contract case.

**Open-source choice:** \( u(0, x_{1os}, \ldots, x_{n-os}, y_{1os}, \ldots, y_{m-os}, t_c) \)

where monetary income is zero, time is at the same level found in the "earn money" choice, and the x's and y's can be positive, negative, or zero since they are measured relative to their values in the contract choice\(^{83}\).

**Notes on Possibilities Frontiers**

Note that the value of the open source choice on the money dimension is almost always zero. Thus on a 2-dimensional plot of money vs. some attribute provided by open source, fun for example, the possibilities set from engaging in open source work alone would look like a ray. On a 2-dimensional plot of two attributes that open source provides, fun and social interaction for example, the technological frontier would (most

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\(^{83}\) For a select few, monetary income related to open source may not be zero, e.g. consultants, book authors, etc. The study will be alert to this to ensure that this assumption is warranted. "Occasionally, the reputation one gains in the hacker culture can spill over into the real world in economically significant ways. It can get you a better job offer, or a consulting contract, or a book deal. This kind of side effect, however, is at best rare and marginal for most hackers; far too much so to make it convincing as a sole explanation... (Raymond 1999, pg. 79)."
likely) be a “2-dimensional” curve. Because of the benchmarking, the possibilities set generated by open source work might lie in any quadrant on the graph.\textsuperscript{84}

The value of contract work on any attribute, except money, is benchmarked to zero. Thus on a 2-dimensional plot of money vs. any attribute, the possibilities set resulting from contract work alone would look like a ray; on a 2-dimensional plot of any attributes (excluding money), the possibilities set resulting from contract work alone would be a point at the origin.

Chart 3-5 provides one example of what a possibilities frontier might look like for the trade off between wealth and an attribute a (keep in mind that an individual may have many more attributes to consider). In this example, attribute a is an experiential or obtained attribute generated in greater amounts by open source work than by contract work. Attribute b might be fun, challenge, learning, or social interaction. Wealth is generated by contract work, but not by open source work. If an individual were to engage in either open source or contract work alone, his possibilities frontier (choice set) would be a ray along a particular attribute axis; however, for any specified time allocation, the possibilities “frontier” would simply be a single point ($a_{\text{max}}$ for OS work alone, $w_{\text{max}}$ for contract work alone). Given time allocated $\hat{t}$, if the individual engages in OS and contract work, his possibilities frontier would be the curve shown.

\textsuperscript{84} To simplify, if a set of generated attributes lay outside of the first quadrant, the “opposite of” one or both attributes can be plotted instead so that the generated attributes lie in the first quadrant.
CHART 3-5:
EXAMPLE POSSIBILITIES FRONTIERS FOR CONTRACT WORK, OPEN SOURCE WORK, AND COMBINATIONS OF THE TWO

From the chart above, it quickly becomes apparent that, given a specific allocation of time, an individual who values both money (or any other attribute offered by contract work and not by OS work) and some attribute offered by open source work but not by contract work is unlikely to be able to reach his or her optimal bundle, \( \hat{z} \), for any given level of effort by engaging in either contract or open source work alone. This individual must engage in both types of work to reach \( \hat{z} \).

3.3.2 Revealed Preference

There are two methods by which to determine individual preferences: observing so called “revealed preferences” and asking individuals about their preferences through

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85 The same argument holds for attributes that may be generated by both open source and contract work, but where some valued attributes are generated at higher rates (per unit time) by engaging in contract work and some attributes are generated at higher rates by engaging in open source work.
questionnaires and/or interviews. Revealed preference argues that preferences are revealed by actions; it assumes that if an individual chooses one set over another, the individual must prefer the chosen set.

In organizational and experimental economics, revealed preference is generally considered the method of choice, because it focuses on those actions and behaviors that individuals have actually chosen. Revealed preference can be used to separate the possible effects of two (and sometimes more) potential motivations. For example, Stern used revealed preference in order to study how the job choice of scientists might be affected by their individual tastes for engaging in research and publication versus their taste for higher incomes (Stern 1999). He studied post-doctoral biologists who received multiple job offers. From the choices they actually made, Stern was able to conclude that firms that allow their employees to publish, on average, extract a 25% wage discount conditional on scientific ability.

In a setting where many potential motivations may exist and where we want to differentiate between these motivations, the observation of revealed preference requires that we observe individuals making multiple choices along multiple dimensions. This requirement poses three challenges in the open source context. First, the choices between Java development activities that a developer has to make are limited and many potential options may be quite similar. Second, individuals may exhibit the same or very similar behaviors for different reasons and revealed preference cannot distinguish between these reasons. Third, in deciding to join or not join an open source community,

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86 Revealed preference is a strong tool and is employed where appropriate and possible within this study.

87 While the observation that some developers have chosen to do open source work tells us that these developers may value other attributes more than money, revealed preference cannot tell us what attribute(s) the developer prefers.

88 We may be able to infer something from observing what communities a developer may have examined and then chosen to join/not join, but these inferences would be largely based on “observable” characteristics of the community and may or may not correctly represent a developer’s true decision criteria (see the next two challenges discussed above). If we could observe a developer choosing among contracts offered to him at the same time, we could draw conclusions based on revealed preference, so long as the contracts were different with regards to the attributes being studied and the developer was choosing among many contracts.
an individual is not making a commitment to take on any particular responsibilities or fulfill any particular functions. Many of the benefits an individual hopes to and actually does derive from open source participation are dependent upon the tasks an individual voluntarily chooses to take on, create, and manage — and the developer can leave the community at any time. This is in stark contrast to a scientist choosing between multiple job offers, each of which require that he engage in certain types of activities in exchange for an agreed upon wage. In this type of setting, asking individuals about their motives is a necessary complementary methodology that must be used in order to distinguish between multiple individual-specific motivations and preferences.89

In the context of open source software development, the only choices that can be observed are that some people choose to do nothing, while others choose to do contract work, take part in open source projects, or engage in both contract and open source work. From the fact that a specific developer chooses to do open source in the presence of a contract alternative, we can infer three things90. First, the increase in utility from all attributes of open source must at least offset the decline in utility from forgone contract wages. Second, the level of at least one attribute of open source must be higher than for contract work. Third, the wealth equivalent of the open source alternative must be greater than the contract wages.91

89 Jencks, et al ask respondents a series of questions in order to understand what job and task attributes define a good job (Jencks, Perman et al. 1988). A similar methodology will be used here.

90 The Availability of the Contract Choice: In a frictionless spot labor market for the work of software developers, developers would always have a choice between allocating discretionary time to paid contract work or to voluntary open source work. This choice only exists in a frictionless or nearly frictionless labor market. In a high friction labor market the contract programming alternative might not be available to most individuals. There appear to be two potential sources of friction. First, developers who hold day jobs might be prohibited by their employers from engaging in contract work. Second, the sunk costs of entering the contract labor pool might be high, meaning that developers might have to invest a considerable amount of time searching for and/or negotiating a contract. If frictions exist, revealed preference tells us even less than it normally would: in a frictionless market we know that Woe > wc, in a market with friction, we only know that Woe > wc − costfriction.

91 Woe is the amount of money such that the utility derived from allocating time tc and receiving Woe is equal to the utility derived from allocating tc and receiving the bundle of attributes associated with open source work.
Formally, if the developer spends $t_{os}$ on open source work in the presence of a contract alternative, then:

$$u(0, x_{1os}, \ldots y_{mos}, t_{os}) > u(w_c, 0, \ldots 0, t_c);$$

at least one $x_{os}$ or $y_{os} > 0$; and

$$W_{os} > w_c.$$

Here $t_{os} = t_c$, by construction. In these expressions, only the bold variables, $t_c$, $t_{os}$ and the amount of foregone wages, $w_c$ are observable. The identity and amounts of the attributes $x_1 \ldots x_n$ and $y_1 \ldots y_m$ in the forgone bundle are unknown, as is the value of $W_{os}$.

Thus the identity, value, and ordering of attributes important to software developers engaged in open source development and the form of their utility function cannot be determined by observing their actions only. In order to learn more about individual motives for participating in open source work, it is necessary to go beyond “pure” revealed preference and ask individual respondents about their preferences through interviews and/or surveys.

**Section 3.4: Conclusion and Application: Improving Our Understanding of What Drives Skilled Software Developers**

In this study, I will assume that OS developers make their choices consciously and rationally – that they allocate time in the same way that economic theory assumes consumers choose among bundles of consumption goods, subject to a budget constraint. Hence, if there are unconscious motivations or cognitive misperceptions that influence developers’ choices, those will not be uncovered by this study. Still it seems appropriate to begin by investigating what OS developers believe they are getting in return for their time, before considering whether their beliefs and choices are or are not rational\(^{92}\).

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\(^{92}\) Only after we understand what individuals think they are doing can we seek to uncover potential cognitive biases.
There exist many competing and contentious theories of developer motivation\(^93\). The framework described in this chapter allows a large set of motives to appear and be distinguished from one another. This study will attempt to distinguish between the forms of the multi-attribute utility function outlined in section 3.1.3, uncover whether or not a dominant form exists, and identify the attributes that motivate developers in the groups studied. A number of hypothesis will be able to be tested: for example, whether the motives of individuals are simple or complex, whether motives are homogeneous or heterogeneous within groups, and whether motives are the same or different across groups\(^94\). The population is however allowed to be heterogeneous, so it is possible that none of the four basic models of motivation proposed (null, alternatives 1, 2, 3) will be rejected and no single dominant form will be identified.

Data will be gathered through interviews, surveys (not included in thesis), and observed behavior on community archives. The experimental design for this study will be discussed in greater detail in Chapter 4. This study will not deliver simple answers in the form of accepting or rejecting a single hypothesis. Instead, this study will shed light on the composition and identity of motives espoused by individuals in three distinct populations of software developers: contract developers, open source developers, and gated source developers. Because the data being gathered is framed in relation to

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\(^93\) Some theorists view open source participation in terms of wealth, effort, and a single additional attribute. Such arguments are a step towards "unpacking" the utility function and are elegant in their minimalism, but they still overlook the potentially complex and heterogeneous nature of the motivations that influence individual choice. Such arguments are, in effect, attempting to invert \(V\) to find a single attribute whose wealth equivalent is greater than \(w_c\). \(V\) provides a mapping between the chosen bundle and its wealth equivalent: \(V: \hat{Z}(t) \rightarrow W\). Earlier it was argued that \(V\) is not necessarily invertible because several different bundles might generate the same wealth equivalent). Such an inversion presumes that the developers’ utilities have a very specialized three-attribute form, \(u(w, X, e)\). While this might be true (or true for some developers), it is a very strong assumption to take as an a priori, descriptive axiom. Empirical data is needed.

\(^94\) In addition, the general multi-attribute framework can be adapted and used to examine the possibility that individual motivations and actions may change over time, to distinguish between motives related to actually doing work and motives related to freely contributing that work, or distinguish between motives expressed by developers of different types, e.g. who occupy different roles, positions, or who contribute in different ways.
existing theories, findings from this study can also serve as stylized facts for subsequent theory building.
CHAPTER 4

UNDERSTANDING THE NATURE OF PARTICIPATION & COORDINATION IN OPEN AND GATED SOURCE SOFTWARE DEVELOPMENT COMMUNITIES

Abstract

Voluntary product development communities have no paid staff or management and may even be geographically dispersed, yet they provide participants with a social context and the resources to create useful products that have, on occasion, displaced or significantly improved-upon commercially-produced products. Such communities represent a very different type of organizational structure for innovation—a structure that we understand little about. This paper explores the motivations of participants from two software development communities and finds that most participants are motivated by either a need to use the software or an enjoyment of programming. The latter group, hobbyists or enthusiasts, are critical to the long-term viability and sustainability of open source software code: they take on tasks that might otherwise go undone, are largely "need-neutral" as they make decisions, and express a desire to maintain the simplicity, elegance, and modularity of the code. The motives of hobbyist evolve over time; most join the community because they have a need for the software and stay because they enjoy programming in the context of a particular community. Governance and licensing structures affect this evolution.
Section 4.1: Introduction

 Individuals are voluntarily contributing their time, skill, and energy to innovation and product development communities. These communities have no paid staff or management and may even be geographically dispersed, yet they provide participants with a social context and the resources to create useful products that have, on occasion, displaced or significantly improved upon commercially-produced products. Such communities represent a very different type of organizational structure for innovation – a structure that we understand little about.

This paper focuses on one aspect of community-based product development: Why do participants voluntarily work within and contribute to communities that provide, support, and maintain a public good? This paper takes an inductive approach and develops a model to understand participation in product-development communities. Participants of two large and well-known software development communities are studied. One community is “open source” and the other is “gated source” – this means that the communities are governed by different institutional structures and intellectual property licensing arrangements, although both communities seek to attract the efforts of volunteer software developers and allow source code (not just binary code) to be distributed. This distinction is exploited and used to develop the model. It is important to note that, as used here, the terms open and gated source refer to two different and distinct modes of development; one is not a subset of the other\textsuperscript{95}. Data were collected via interviews and analysis of publicly available project information.

Empirically, we see that two types of participants emerge. In the first, more populous group, a need to use the software drives product creation and improvement, while notions of fairness or the desire to benefit from the potential and subsequent improvements of others leads people to contribute what they know to the community. In the second, much smaller, group, participants do work that is largely unrelated to their own needs. These participants derive enjoyment from engaging in creative and

\textsuperscript{95} A more detailed explanation of open source and gated source software development is provided in the Appendix.
challenging programming tasks, working with others, and seeing the software improve. They primarily undertake tasks that interest them, thus the tasks they choose are not always those for which the project has the greatest need or for which the most users express an interest. Nevertheless, feedback from users and developers of the code is also a vital component of the system for these developers. Over time, members of the second group of participants acquire a greater understanding of larger and larger portions of the software code. Many of these individuals express a dedication to keep the design of the software simple and understandable – so that others can continue to improve upon and “play with” the code. This desire to write and maintain an elegant codebase is critical to the continued viability of the community and code. The formal and informal processes of the open source community support these types and quantities of participation. Overall, the formal and informal processes of the communities allow individual contributions to be transformed into high-quality products without the need for paid or full-time staff or hierarchical mechanisms for task coordination.

Theory from the literature on fairness and social exchange in the fields of evolutionary psychology and behavioral economics, as well as theory and empirical findings from the innovation management literature, are used to understand and explain OS software development communities. The model developed in this paper helps us understand how high-quality products are generated without direct control over participant actions by a volunteer “staff”; how these individuals accumulate the knowledge required to manipulate the code96; and why talented software developers, most of whom hold full-time jobs and have significant demands on their time, are participating in open source development projects. The model also shows why different institutional structures may result in different amounts and types of participation, and is therefore useful to firms interested in creating communities to attract volunteer developers. The model is compared with the traditional employment model.

96 Software development requires high levels of expertise. In commercial software development, complexity can create significant barriers for new developers and users. As a software program grows, changes and becomes more complex, only a few people who have been actively involved in its development over time might fully understand the software architecture and be able contribute additional code. (Fichman and Kemerer 1997)
Motivation for Study

From a pragmatic standpoint, the motivations of open source and gated source software developers are of interest to academics and practitioners for three primary reasons. First, individual developers are voluntarily doing work that appears similar to work that commercial firms would pay them to do. This challenges commonly-held beliefs and theories in economics and management studies. An understanding of motivation is fundamental to human resource management and the design of organizations. A firm that provides developers with highly valued benefits might be able to create a more attractive work environment, thereby increasing the firm’s ability to attract and retain a highly skilled workforce.

Second, the presence of open source communities affects the strategic direction taken by software firms (Valloppillil 1998). Understanding the motivations and behaviors of community participants brings us a step closer to understanding where such communities are likely to appear and be successful. Because open source software competes with proprietary software, such information may be strategically useful to commercial firms deciding whether or not to enter, remain in, or exit markets where communities currently exist or are likely to enter.

Third, open source software development is an example of a new (to academics and some practitioners) and interesting model of innovation and product development. The assumption that for-profit firms and entrepreneurially-minded individuals are the primary sources of innovation runs deep. However, as a key assumption, it limits our exploration and understanding of the innovation process as it occurs outside of firms. Individuals outside of firms innovate frequently and are the source of important innovations in several product categories studied to date. We currently know little about the complex motivations and social behaviors of individuals involved in this process. Open source and gated software development are representative of a “community-based” model for generating products and innovations. Such open and voluntary collaborative
technology development processes are not unique to software; they exist in other industries and product areas.

The paper is structured as follows. The existing literature on motivations for participation in voluntary product development communities is discussed in Section 4.2. The research sample and inductive methods are described in Section 4.3. Research findings are reported Section 4.4 and discussed in Section 4.5. A model of participation that focuses on the effects of evolving motives and its implications is discussed in Section 4.6. Section 4.7 concludes.

Section 4.2: Literature Review

4.2.1 Community-Based Innovation & Product Development: A Different Mode of Organizing

Much research has focused on the provision of resources in product development organizations, inter- and intra-firm product development-related communications, innovations made by user firms and component suppliers rather than manufacturers of the product (Enos 1962; Knight 1963; Freeman 1968; Allen 1977; von Hippel 1988; Ancona and Caldwell 1992; Brown and Eisenhardt 1995). In contrast, the academic literature to date virtually ignores product development and innovation activities occurring outside the boundaries and structures of firms.

A handful of existing studies, as well as autobiographical accounts and histories of technology, indicate that innovative activity routinely occurs outside of firm in a variety of product areas, including software, electronic components, automobiles, and sporting equipment (Salus 1994; Kline and Pinch 1996; Franz 1999; Raymond 1999; Luthje 2000; Haring 2002; Franke and Shah 2003). Such activities have existed for many years and can produce novel products competitive with those produced by firms (Pugh, Johnson et al. 1991; Salus 1994; Franz 1999; Raymond 1999; Shah 2000; von Hippel 2001).
While some innovators and product developers outside of firms may have worked alone, it appears that many worked jointly with others, either face-to-face, or by communicating through newsletters, journals, magazines, and occasional meetings or conferences, and/or electronic or on-line communication (Salus 1994; Franz 1999; Raymond 1999; Shah 2000; Haring 2002). Recent research has found that individuals working within such communities tend to share information freely with other community participants and often receive assistance from others (Franke and Shah 2003). In addition, they solve problems and design prototypes using information within their existing knowledge domain and often engage in customizing the product for their own use and for their friends (Luthje, Herstatt et al. 2002; Franke and von Hippel 2003).

“Communities” are composed of loosely-affiliated individuals with common interests. They are characterized by a lack of formal coordination and the free flow of information. These characteristics allow for rich information and feedback and the matching of problems with individuals who possess the ideas and means to solve them. Due to the varied skills and needs of individuals involved, user communities are generally well-equipped to identify and solve a wide range of design problems.

4.2.2 Motivations for Participation, Creating Code, and Sharing Information

The relatively recent success of two open source software products, the Linux operating system and Apache web server, has piqued academic and general interest in the open source phenomenon. Not surprisingly, a number of explanations for the phenomenon have been suggested. This section reviews existing explanations for why individuals participate in open source software development communities and for two sets of specific actions undertaken by participants: (1) creating and analyzing information (e.g. writing software code to address an issue) and (2) sharing that information with the community.

97 The concept of community employed in this study is an emic one. The websites of both software development projects studied prominently emphasize the importance of “community” in developing high quality software and use the term descriptively: “The community factor is an essential component ... We value communities more than software...”
Motives for Participation

What do people participate in the creation of open source software? Many competing and contentious theories of motivation have been put forward to answer this question. For example, some argue that political ideology and anti-corporate sentiment fuels open source development. Others argue for the preeminence of enjoyment and creativity, satisfaction of user needs, building a reputation within the community, a need for affiliation, a desire to create or maintain an identity, or training. Table 4-1 provides an overview of existing explanations for participation. Note that an individual may possess multiple motivations and different individuals may possess different motives that influence the choices they make (Jencks, Perman et al. 1988; Jensen and Meckling 1994; Stern 1999; Benkler 2002).

Two relatively large academic survey-based studies on general motives for participation in free and open source software development have been conducted (Niedner, Hertel et al.; Ghosh, Glott et al. 2002). These studies find that motives related to needs for software, improvement in skills, and enjoyment are especially important. Table 4-2 summarizes the key findings of the Niedner, Hertel, et al study. The findings of the Ghosh, Glott, et al study are similar.
<table>
<thead>
<tr>
<th>Motive</th>
<th>Example</th>
<th>Selected References</th>
</tr>
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| Need For Product               | Participating in order to create, customize, or improve a product or feature | Raymond 1999  
Kuan 2000  
Franke & von Hippel 2003 |
| Enjoyment, Desire to Create and Improve | Participating because one enjoys it; finds creating or improving software creative and interesting | Weizenbaum 1976  
Bailyn 1983  
Gelernter 1998  
Linus Torvalds 1998  
Gabriel & Goldman 2001 |
| Reputation and Status Within the Community | Participating in order to build or maintain reputation or status within the community | Rheingold 1993  
Raymond 1999  
Gabriel & Goldman 2001 |
| Affiliation                    | Participating in order to socialize or spend time with like-minded individuals | Haring 2002  
Raymond 1999 |
| Identity                       | Participating in order to reinforce or build a desired self-image       | Haring 2002                                  |
| Values, Ideology               | Participating to promote specific ideals, e.g. the free-software philosophy | Raymond 1999  
Gabriel & Goldman 2000  
Stallman 2001 |
| Training: Learning, Reputation Outside The Community, Career Concerns | Participating to improve one’s skills, with the belief that such improvement will lead to a better job or promotion | Raymond 1999  
Lakhani & von Hippel 2000  
Lerner & Tirole 2000  
Lancashire 2001  
Hann 2002 |
<table>
<thead>
<tr>
<th>Item</th>
<th>Importance</th>
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</thead>
<tbody>
<tr>
<td>Facilitating my daily work due to better software</td>
<td>4.6</td>
</tr>
<tr>
<td>Improving my programming skills</td>
<td>4.6</td>
</tr>
<tr>
<td>Having fun while programming</td>
<td>4.6</td>
</tr>
<tr>
<td>Personal exchange with other software developers</td>
<td>4.2</td>
</tr>
<tr>
<td>Career advantages due to experience gained in Linux projects</td>
<td>3.7</td>
</tr>
<tr>
<td>Gaining a reputation as an experienced programmer inside the Linux community</td>
<td>3.5</td>
</tr>
<tr>
<td>Time loss due to my involvement in Linux</td>
<td>2.6</td>
</tr>
<tr>
<td>Lack of payment for my work on Linux</td>
<td>2.2</td>
</tr>
</tbody>
</table>

*Source: University of Kiel Survey Study (Niedner, Hertel et al.)*
Motives for Creating & Analyzing Code

In this section, motives for a specific "work" activity - creating and analyzing code - are discussed. The distinction between intrinsic and extrinsic motivation might be helpful in understanding the type and quantity of an individual's participation with regards to creating and analyzing code. When a person adopts an intrinsic motivational orientation, his primary focus is on the rewards inherent in engagement with the activity; the activity is approached as an "end in itself" (Kruglanski 1975). In contrast, when a person adopts an extrinsic motivational orientation, her primary focus is on rewards that are mediated by but not part of the target activity; the activity is approached as a "means to an end" (Kruglanski 1975). Intrinsically rewarding activities are associated with characteristics such as novelty, entertainment value, satisfaction of curiosity, and opportunities to experience and attain mastery of a particular topic or skill. In contrast, extrinsically rewarding activities are associated with a desire to quickly, predictably, simply, and easily complete the task.

An individual's motivational orientation towards a task may be malleable; for example, when individuals are given external rewards for engaging in an otherwise intrinsically motivating activities, the individuals are less likely to engage in that activity in the absence of the reward and perceive the activity as less intrinsically motivating (Deci 1971). From this perspective, developers may view software development in the context of open source as intrinsically motivating, whereas software development at work - with deadlines, guidance from project managers, etc - may be viewed as something one does primarily to earn a paycheck. The products of work done under different motivational orientations may differ in quantity and quality along a variety of dimensions, including creativity (Amabile 1983; Amabile 1985).

Individuals seek out engaging and intrinsically motivating activities from rock-climbing to chess-playing (Cziksentmihalyi 1996). Engineers are no different, except that the activities they choose may be similar to those they do at work. Haring reports that many amateur radio enthusiasts who built and improved their own equipment as a hobby were engineers - some even worked for radio and electronics manufacturers
(Haring 2002). Bailyn & Lynch (1983) report that engineers with a “puzzle orientation” who do not find adequate stimulation and challenge at their day jobs tend to engage in a variety of technical activities (e.g. improving their cars, building models) in their discretionary time. At least some engineers who do not find “enough” satisfaction in their day jobs have hobbies (like open source software development) that use their engineering skills.

**Motives for Sharing Code or Other Information**

One might expect individuals (or firms) to guard any information that they believe is valuable. However, we observe participants of innovation and product development communities sharing information regularly, and often even commenting on the usefulness of a particular change or addition. It is possible that these individuals see no reason not to share the information, especially if they do not plan to commercialize or otherwise profit from it. Even in that case, however, individuals bear the costs of communicating the information they possess. In this section, three sets of explanations for why information is shared are discussed.

From a sociological perspective, Kollock discusses four motivations that might lead an individual to contribute valuable information to an online group: (1) the expectation that one will receive useful help and information in return, that is, an anticipation of reciprocity, (2) a desire for prestige or status within the group, (3) an increased sense of self-efficacy derived from the act of contributing, and (4) a felt attachment or commitment to the group or project that leads the individual to act in the group’s interest (Kollock 1999).

From an economic perspective, it may be beneficial for an individual to reveal innovation or product-related information, if sharing (1) induces improvements by others, (2) sets an advantageous standard, (3) does not assist competitors, and (4) leads to gains from reciprocity and reputation effects (Harhoff, Henkel et al. 2000). Lerner and Tirole focus on career concerns as the primary factor which may lead an individual to share
information and code with others, e.g. a need to learn new skills or a desire to benefit from reputation earned within the software community (Lerner and Tirole 2002).

From a psychological perspective, perceptions of fairness may weigh heavily into an individual’s decision to work with others. Work in psychology and behavioral game theory suggests that an individual’s willingness to cooperate is highly contingent on assessments of the expected level of cooperation from others. For example, the following factors have been found to mediate an individual’s willingness to contribute in public goods experiments: (Dawes and Thaler 1988; Rabin 1998, pg. 21-24) (1) beliefs or observations regarding how much others have or are contributing, (2) pre-decision communication, and (3) judgments regarding the behaviors, motivations, and intentions of those who might benefit. In one set of experiments, levels of contribution declined when the same set of players engaged in repeated trials of a public goods experiment with the same group. However when players were told that they would play the game several more times with a different group, contributions at the start of the second round went back up to virtually the same rate observed on the initial trial of the first round (Dawes and Thaler 1988, description of experiments conducted by others). The exact reason for this is not known, but it appears that individual beliefs regarding what constitutes fair behavior influence actions in situations where little is known about the opposing party, regardless of prior experience with different actors.

Kahneman, Knetsch, and Thaler (1986a, 1986b) also find experimental evidence for three “rules” of fairness: (1) individuals care about being treated fairly and treating others fairly, (2) individuals are willing to resist the actions of unfair parties even at a positive cost to themselves, (3) individuals have systematic and implicit rules that specify which actions are considered fair and unfair. From where do these “rules of fairness” arise? Evolutionary psychologists and biologists continue to gather evidence supporting the idea that specific cognitive adaptations in the human mind exist for reasoning about social contracts. These adaptations are finally honed for “cheater detection” and can assess the costs and benefits of a social contract from the perspective of different parties (Barkow, Cosmides et al. 1992, pg. 206).
Section 4.3: Method, Setting & Data

This research project uses an inductive research approach, based on the principles of grounded theory building, to better understand the motives and actions of individuals involved in voluntary software development communities. The main questions we sought to answer were: Why do participants voluntarily work with and contribute to community-based product development projects? How are their work efforts and products coordinated? Grounded theory building is particularly useful in situations where the phenomenon does not fit existing categories or is not readily explained by existing theories (Glaser and Strauss 1967). Grounded theory building is a well-accepted methodology among qualitative researchers in sociology, and is used in strategy and technology and innovation management as well (Dougherty 2002). It has three distinct requirements: theoretical sampling, making constant comparisons, and using a coding paradigm to ensure conceptual development (Strauss 1987; King, Keohane et al. 1994).

The primary data collection method used in this study was interviews with participants of voluntary software development communities. As a result, the unit of analysis reported on here is the individual software developer. However, in the interviews, particular attention was paid to the individuals’ perception of the community as a social system - the community’s goals, “norms and values, local status symbols, social cleavages, and how all these shaped peoples’ lives and the community’s functioning.” Our assumption was that each software developer was choosing how to invest her time. The choices she made, we conjectured, would depend greatly on the social system surrounding her; and her choices would affect that system as well (Coleman 1994, pg. 32-34).

4.3.1 Factors Guiding Choice of Setting

As mentioned earlier, there are two categories of voluntary community-based software development: open source development and gated source development. Both types of communities seek to attract volunteer developers and allow developers to view the source code, however different governance principles apply in each community. I
chose to study participation in both types of communities in order to see if differences affected the type, quality, and reasons for participation.

The key distinctions between the open and gated source communities studied are as follows. In the open source community, anyone can download, use, modify, and distribute the code. In the gated source community, the corporate owner of the code specifies the terms of the license and how decisions will be made in the community. Only those who have agreed to a license with the corporate owner can download, use, or modify the code. In addition, in gated communities, some types of use require the payment of a royalty to the corporate owner of the code and there are generally restrictions on code distributions. See the Appendix for more information.

Interviews with six open source software experts and internet searches were conducted in order to gain a better understanding of software development and identify potential communities to study. The two communities studied here were chosen due to their similarities on several dimensions. By selecting for similarity on these dimensions, the behaviors of individuals within these communities could be compared as in a natural experiment.

The two communities are similar in the following ways. Both have a large number of participants; are well known within the software development community; are of roughly the same age; and use the same programming language, thus the pool of developers familiar with or wanting to learn the language would be the same size. The codebases produced by these communities are most often used by developers to develop other software or software applications. The initial code for both communities was developed by the same corporation. Finally, both communities serve as "umbrella" organizations for several projects. Representative projects within each community were chosen for study with the help of community experts.
4.3.2 Data Collection & Analysis

Data from four primary sources informed the study. Multiple sources of information enabled triangulation and validation of theoretical constructs.

(1) **Mailing-Lists:** I read all postings to both the project-specific and general mailing lists for both communities studied for a three month period preceding the interviews. Over 2000 messages were posted during this time period. Reading them allowed me to gain familiarity with the types, quantity, and content of discussion and interaction – and the contributions and roles of different individuals.

(2) **Interviews:** I conducted over 60 semi-structured one-on-one interviews with volunteer community participants between December 2001 and March 2002. The majority of interviews were conducted by telephone and tape recorded. Interviews lasted from 30 to 150 minutes.

Interview questions focused on gaining an understanding of early and current participation; methods of processing mailing list information; type of work done; background; current employment context; and the decision-making, governance and ownership practices used within the project. At the conclusion of the interviews, participants were asked to comment on explanations for participation cited in the literature that they had not brought up.

Informants were chosen to maximize variance on the following dimensions related to participation:
(a) **Length of participation.** Defined as length of time since first post to a project mailing list: less than 2 months, more than 2 months (data on the exact length of time was also collected).
(b) **Current frequency of participation.** Measured by number of posts made to mailing lists in the preceding one-month time-period: 1-2, 3-10, more than 10.
(c) **Type(s) of contributions made to mailing lists**: Did the participant pose questions, provide answers or suggestions, make bug fixes, contribute code, participate in general discussions, or engage in a combination of the above activities?

(d) **Individual's role within the community**: Was the participant a user, developer, "committer" (a participant who has been granted "write access" to the source code repository. Applies to the open source community only), or employee of corporate owner (applies to the gated source community only)?

Information on these dimensions was gathered from observed behavior on project mailing lists (a, b, c) or other project-related documentation (d).

(3) **Conference Observation**: I spent 3-days (approximately 28 hours) observing and meeting with attendees at a technical conference focused on the gated source project.

(4) **On-line Project Documentation**: In addition, I analyzed other project data archived on the Internet, which detailed project interactions and developments. Project data collected from online archives includes project descriptions, charters, bylaws, meeting minutes, mailing list archives, and one informal survey of the "committers" belonging to the open source community. The survey focused on motivations for participation. It was distributed by email and the results were published on the Internet approximately 9 months after this study's interviews were completed.

Interview notes and other qualitative data were coded and analyzed in accordance with grounded theory principles. The variance in the data collected through theoretical sampling facilitated the process of constant comparison and the development of codes and constructs.

Interviewees were guaranteed anonymity to promote candid responses. For this reason, the names of the individuals interviewed, as well as the names of the open source and gated source communities and projects studied are withheld.
4.3.3 Operational Definitions

The following operational definitions were used for data categorization and analysis:

*Participant*: posted at least one message to the mailing list\(^98\).

*Short-term participant*: a participant for less than two months at the time of interview.

*Long-term participant*: a participant for more than two months at the time of interview.

*Committer*: a participant who has been granted "write access" to the source code repository (only applicable to participants of open source communities).

Section 4.4: Findings

The main findings of the study are briefly summarized here and elaborated upon in the following sections. The interviews revealed that short and long-term participants in both the open and gated source communities initially became involved because they needed to use the software. Among those who remained in the open source community, a subset began to work on the project as a hobby. In contrast, virtually all long-term gated source participants continued to be motivated by a need to use the software.

Both interview and archival data indicate that hobbyists are critical to the long-term viability and sustainability of open source software code. They take on tasks that might otherwise go undone and generally make decisions based on what would be best for the code and the community using the code. In interviews, they express a desire to maintain the simplicity, elegance, and modularity of the code.

Section 4.4.1 describes the characteristics of individuals in the sample. Section 4.4.2 discusses communication within the communities. Reasons for creating & analyzing information are discussed in Section 4.4.3 and reasons for contributing information – fairness, feedback, building a better mousetrap – are discussed in Section

\(^{98}\) It is assumed that many people download and use the software, yet never post a message on the mailing list. Very little is known about such individuals. For this group, the software serves its purpose without additional work, the individual is able to do this work on their own, or the individual receives assistance from sources outside the on-line community. Such users of open source software cannot be contacted directly since open source communities do not keep a record of who downloads the software; such users of the gated software have signed the licensing agreement, however their names are known only to the corporate sponsor.
4.4.4. Formal and informal community rules and processes that support these motives and assist coordination are discussed in Section 4.4.5.

4.4.1 Characteristics of Individuals in the Sample

The sample was comprised primarily of college-educated males in their mid-twenties to mid-thirties; only one female was interviewed. The majority held full-time jobs as software developers or engineers. A few were employed by software consulting firms and very few were independent contractors. The characteristics of interviewees in the gated and open source communities were similar and are reported in Table 4-3. Note that the sample of 45 referred to in this and all other tables includes (1) only those developers not employed by the sponsor of the corporate community, and (2) the theoretically sampled interviewees only (not interviews with experts or other individuals).

The amount of time the participants spent doing project-related work varied greatly both across individuals and over time within individuals. At one extreme were participants who downloaded the software and encountered a very minor problem when deploying it. At the other extreme were several participants who spent 2-3 hours per day (occasionally more), 4-6 days per week on project related activities, many of these individuals have been active for well over 6 months.
<table>
<thead>
<tr>
<th>TABLE 4-3: SAMPLE CHARACTERISTICS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Short-Term Participants</strong></td>
</tr>
<tr>
<td><em>(n = 10)</em></td>
</tr>
<tr>
<td><strong>Age Range</strong></td>
</tr>
<tr>
<td><strong>Highest Education Level</strong></td>
</tr>
<tr>
<td>High School</td>
</tr>
<tr>
<td>BS/MS</td>
</tr>
<tr>
<td>ABD/PhD</td>
</tr>
<tr>
<td><strong>Employed when Interviewed (Students)</strong></td>
</tr>
<tr>
<td><strong>Married or Committed</strong></td>
</tr>
<tr>
<td><strong>Have Children</strong></td>
</tr>
</tbody>
</table>

n = 45; *5 unknown, n = 23; *2 unknown, n = 5
4.4.2 Modes of Communication

A defining characteristic of the open source project studied was that virtually all interchange between participants took place in a public forum. The primary means of communication between participants was via the community mailing lists. Thus documentation of virtually all communication was available on the public archives. Note however that a few of those interviewed asked for the assistance or opinions of co-workers at their place of employment before checking public archives for information or sending an email to the community.

The pattern was quite different within the gated source community. Although a great deal of communication took place on the mailing lists, a larger fraction of interviewees report private and off-line communication (1) with the corporate sponsor about the software code or licensing terms, (2) with co-workers, and even (3) with other community participants. Thus it appears that much more work was done off-line in the gated project studied.

4.4.3 Reasons for Creating & Analyzing Information Evolve Over Time

As indicated above, open and gated source participants are generally motivated by need, although a subset of long-term open source participants are motivated by the fun and challenge that come with writing and understanding software code. Individuals in the latter set generally joined the community because they had a need, but, over time, began participating for the fun of it. Many of these individuals now consider open source software development a hobby. A corresponding transition from need-based to fun-based participation was not observed in the gated source community.

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99 There were very few other exceptions to this rule. Occasionally a committer reported emailing other committers to let them know that they would not be contributing for a while due to work or personal reasons. Very occasionally a committer reported emailing another developer to ask if they would be interested in becoming a committer before making the suggestion publicly. A few community participants report meeting at conferences or local user group meetings (either broadcast to the group prior to the conference or occasionally at random when names are recognized). A few community participants mentioned conducting very specific technical discussions over IRC. The results of these technical discussions were always posted on the project mailing lists.
Initial Involvement: A Need for the Software

When describing their initial involvement with open or gated source software, virtually all interviewees spoke of needing to use the software for work-related purposes (Table 4-4). Their needs and the extent to which they had to manipulate the software to meet those needs varied widely, e.g. some had questions about how to use the software in a particular context, while others needed to write a new feature for their own purposes.

"I was using the software for work. It's excellent, but there was a feature that I wanted that was not there.... I searched the documentation and mailing lists for information and to see if I had overlooked something, finally I asked a question. That spurred some conversation and someone suggested a beautiful way to implement the idea."

— Short-term participant, open source community, USA, age 29

Many made the choice to use open source software, rather than commercially-available software specifically because they could view and change the code to best fit their own needs.

Several gated source participants expressed reluctance to use gated software, stating that they would have preferred the software to be open source. The licensing mechanism made it difficult for them to get permission from their managers and/or corporate legal departments to use the software. Many said that the technical capabilities of the gated software were unparalleled and necessary to solve the problems they were working on. Most undertook comprehensive searches for other software options before choosing the gated software.
**TABLE 4-4:**

**NEED FOR SOFTWARE DRIVES INITIAL VOLUNTEER INVOLVEMENT**

<table>
<thead>
<tr>
<th>Reason For Initial Involvement</th>
<th>Short-Term Participants (Open Source/Gated)</th>
<th>Long-Term Participants</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>General Participants</strong> (Open Source/Gated)</td>
<td><strong>Committers</strong> (Open Source)</td>
</tr>
<tr>
<td>Need for Software</td>
<td>9 (7 / 2)</td>
<td>26 (11 / 15)</td>
</tr>
<tr>
<td>Other</td>
<td>1 (0 / 1)</td>
<td>2 (1 / 1)</td>
</tr>
</tbody>
</table>

\[n = 45\]
Long-term Involvement: Volunteers Behave Differently In Open Source & Gated Communities

When asked to describe the reasons for their ongoing participation, virtually all long-term gated source project participants continued to focus on their need for the software. They mentioned specific needs for new functionality or for up-to-date information on changes in the software that might affect them (Table 4-5). The reasons for ongoing participation reported by long-term open source participants were strikingly different (Table 4-6): fewer than half reported continuing their participation because of need.

<table>
<thead>
<tr>
<th>TABLE 4-5: MOTIVES IN GATED COMMUNITIES DO NOT APPEAR TO CHANGE OVER TIME</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Long-Term Gated Source Community Volunteers</strong></td>
</tr>
<tr>
<td><strong>Motive</strong></td>
</tr>
<tr>
<td>Need Software for Own Use</td>
</tr>
<tr>
<td>Other</td>
</tr>
<tr>
<td>n = 16; chi squared = 0.61</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>TABLE 4-6: FOR THOSE WHY STAY IN OS COMMUNITIES, MOTIVES EVOLVE OVER TIME</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Long-Term Open Source Community Volunteers</strong></td>
</tr>
<tr>
<td><strong>Motive</strong></td>
</tr>
<tr>
<td>Need Software for Own Use</td>
</tr>
<tr>
<td>Other</td>
</tr>
<tr>
<td>n = 19; chi squared = 3.76; p &lt; 0.001</td>
</tr>
</tbody>
</table>
"Needless" Long-Term Involvement: Enjoyment

What, if not need, motivates more than half of all long-term open source members interviewed? When describing why they chose to engage in certain tasks, this subset of participants spoke of their open source work as a fun and challenging hobby-like activity (Table 4-7).

"I don’t watch TV or sleep enough... this is my hobby... I won’t work a job that requires more than 40 hours... I want to have breakfast and dinner with my kids... I work on open source after they go to bed."

- Long-term participant, open source community, Australia

In fact, the website of a related project even includes a list of haikus written by developers, many focusing on software development itself. The following example evokes the implicit tension between a seductive hobby and “legitimate” (known to the boss) work.

Time, too much have you
major geeks these people are
boss know you do this? :)

174
TABLE 4-7:
LONG-TERM PARTICIPANTS WITHOUT OWN NEED
FOR SOFTWARE DESCRIBE THEMSELVES AS
MOTIVATED BY CHALLENGE & FUN

<table>
<thead>
<tr>
<th>Primary Motivation for Creating &amp; Improving</th>
<th>Gated Source Community Participants</th>
<th>Open Source Community Participants</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>General Participants</td>
<td>Committers</td>
</tr>
<tr>
<td>Challenge and fun</td>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td>Reputation outside community</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Other (learning, obligation, reciprocity, ideology, etc.)</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

n = 14

These developers focus on the importance of keeping the code elegant and simple, as well as backward compatible\(^{100}\). Because they are also users of the software, they have experience with bad code and an inherent interest in maintaining the quality and backwards compatibility of the code. They see the project as something very useful and meaningful. These preferences guide their choice of tasks, methods of addressing tasks, and choices regarding which suggested features to add or develop and which to exclude from the source code.

"Now that I am a committer I am more concerned about backwards compatibility and other issues; I am more conservative."

- Long-term participant, open source community, Australia

\(^{100}\) Backward compatibility means that a software system can successfully use interfaces and data from earlier versions of the system.
This group contributes to the development of the software in many ways. Importantly, interview data (from members of this group and others) suggests that these participants take care of a great deal of “maintenance work” such as committing code, designing new releases, etc. In contrast, newcomers or infrequent participants identify problems and contribute many of the new ideas.

Note that many committers who participate as a hobby do commit code contributed by others and patch bugs. However they do so when they have the time and desire. Some of these committers are far more active than others. Although bugs are generally addressed quickly, backlogs of code embodying new features or promising greater efficiency often build up. Oftentimes the back-logs are not dealt with until one or more individuals signal that it is time to trigger a new code release - and takes primary responsibility for making sure that the release happens. Committers who reported need (not fun) as their primary motive generally did not commit code unless (a) they had written it themselves, and (2) it pertained to the portions of the code in which they were most interested. A long-term participant motivated primarily by his own need for the software reports:

"Even now I don’t incorporate code into the tree unless I write it... I didn’t write the code... I do make minor revisions... it’s worth it now that I have access."

- Long-term participant, open source community, USA

Participants reported choosing work tasks that were related to the portions of the code they had previously worked on. Several reported that their knowledge of the content and structure of the code accumulated over time, allowing them to undertake more difficult challenges, including those that required an understanding of more than one area (module) of the code. Learning appeared to be a by-product, that is, a reward,
resulting from engaging in challenging and fun work, not a primary driver of the work itself.\textsuperscript{101} \textsuperscript{102}

The types of tasks and work undertaken vary, however virtually all interviewees stressed the fact that the vast majority of the work was done by choice:

"No one makes you do anything here, if you see a need or something that would be fun to work on, you take on the responsibility and do it... you let others know what you are doing, obviously."

- Long-term participant, open source community, USA

"I pick and choose the work that's most interesting to me ... it's great when you find a challenging problem to work on – either on your own or because someone needs it – you can spend hours on it... The routine stuff is okay, but I don't do much unless I just want to hack for a while and there are no really interesting problems around... When I get bored, I'll leave..."

- Long-term participant, open source community, France

\textsuperscript{101} A parallel can be seen in crossword puzzles. Many people enjoy doing cross-word puzzles and are likely to learn some new words in the process; however, they do not do the puzzles to learn new words. Others may engage in solving crossword puzzles in order to learn new words, but they often do not enjoy it in the same way nor will they keep at it for long periods of time.

\textsuperscript{102} The distinction between the skills to write code and knowledge of a particular piece of code is critical. This distinction corresponds to the difference between the ability to read and knowledge of a particular section of the *Iliad*. Most participants pointed out that they had come into the project with the required technical skills and all stated that they learned about the structure of the open source code as they worked. Some reported sharpening or expanding their skills. Whether a willingness to engage in technical problem solving is innate or partially driven by knowledge of a particular piece of software code is not known and would make an interesting topic for future research.
Many open source developers – even those who attained committer status – leave their projects. They are not expected to remain on the project indefinitely and exit is understood to be a normal part of the process. It is common to use and have worked on several open source projects, although most reported that they can only dedicate a great deal of effort to a single project at any one time. The character and behaviors of the other people involved in a project influence participation decisions:

"At some point, the participation decision isn’t about technical considerations. There’s another OS project whose technology I use and I want to develop further, but the “benevolent dictator” is simply a dictator... the few developers who stick around are like that too... who needs that?"

- Short-term participant, open source community, USA

4.4.4 Reasons for Contributing Information

Even if one has made an alteration to the software or understands it well, the costs of contributing this information are positive and often relatively high. Time and effort are required to communicate, e.g. code might have to be cleaned up; thought must be put into what is useful to others and what might be particular to your own needs; comments and explanations must be composed. Despite these costs, many individuals contribute information – either code they have created or knowledge - to the community. The reasons for contributing work vary by individual and over time, but several patterns can be observed. In this section, the role of fairness, the desire for assistance from others, and the desire for feedback on one’s work are discussed.

Several of the individuals interviewed reported that they did not contribute all or part of their work product. The reasons given varied and included: the work product was so specialized that it would be of little use to others; the participant lacked time; and the code was of competitive importance to their firm and hence would be kept proprietary.
**Fairness**

Several short-term participants and a few long-term participants who spoke about the importance of fairness and feelings of obligation in motivating their decision to share information and code with the community. Within the open source project, individuals citing this as a reason were primarily interacting on the “user” mailing list (not the developer mailing list). They reported that “others helped me, so I should help them” and “this is what is done in the community.” After contributing, several interviewees who cited this reason removed themselves from the mailing lists and did not keep up with software-related developments. For these individuals, it does not appear that contribution is tied to seeking reputation-related recognition or future improvements on the contributed code. Both of the two individuals in this category did not know if their code contribution had been accepted and made part of the code (“committed”); they were using the version of the code they had initially downloaded and then altered.

“My questions were answered, the product worked, I took my name off the mailing list.”

- Short-term participant, open source community, USA

**Need For Assistance When Building a Better Mousetrap**

Both short- and long-term participants reported interest in finding better solutions than the ones currently in place. By contributing their own work and ideas, they sought to (1) get feedback from others and, ideally, elicit subsequent improvements, (2) start or sustain discussions or development work that may be helpful to themselves and others, (3) communicate that they had an important need that was worth spending their own time solving and might thus be worthy of the attention of others.

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103 The reasons for this were not explored, but might include that they felt they had contributed enough back, contributed most of what they thought they knew, lost interest, or observed that others — at that time — were not interested in the same issues.
In the process of scanning through the mailing lists for topics related to their own, they often came across questions from others that they knew the answer for and answered them, out of reciprocity or fairness; this pattern of answering questions has been documented in other studies (Lakhani and Hippel 2000).

Only a subset of those who brought up the desire to have an even better solution said that they wanted to get their code incorporated into the source code base so that it would remain in future versions of the code. Several remarked that what was important was having the feature or functionality and that they tried to avoid upgrading to new releases, preferring instead to rely on what they currently had for as long as possible.

Open Source Projects: Feedback on Creative & Useful Work

As discussed earlier, many people work on open source projects because they enjoy programming. However, enjoyment of the act of programming does not necessitate that one contribute or even work within a community (one could work alone). Individuals appear to contribute in order to receive feedback upon their work. Feedback comes from both those who use the product and those who participate as a hobby.

Many participants report monitoring the mailing lists for feedback on the portions of the software they have created and for ideas regarding what interesting problems exist that they might want to work on. In the process, they encounter questions and requests for assistance. They are very selective in choosing what to read and whether or not to respond. Most provide assistance only when (1) others might not be able to answer the question, and (2) when it looks as if the requestor of information will actually make changes and contribute to the project.

"I only take part in developer list design debates that are going to go somewhere... whoever is suggesting has to be asking a "how" question."

- Long-term participant, open source community, USA
Several interviewees mentioned that they felt an obligation to support software they had written. However that obligation was related to helping others understand the code and tinker with it themselves, and not to provide services or customize the software for individuals.\footnote{This makes sense as an action that is fair and promoted future feedback: if users are ignored, they are likely to find other software to use and feedback will decline. If you are having fun as you create the code and enjoy the feedback, answering questions is the least you can do. The mechanism for doing this is partially institutionalized: when asking a question, the requestor is expected to have searched past archives and looked at the code, thus when they email their question to the community they often email the mailing list AND cc any individuals known to have knowledge of the topic. This decreases the search costs for providers of information and increases the likelihood that the requestor will receive a quick response.}

Recognition from one's peers is one type of feedback and may tie into the desire to be creative and engage in challenging tasks.

"...creative programmers want to associate with one another: only their peers are able to truly appreciate their art. Part of this is that programmers want to earn respect by showing others their talents. But it's also important that people want to share the beauty of what they have found. This sharing is another act that helps build community and friendship."

- Expert, USA

Attaining "committer" status is an additional form of feedback in the open source community. This lets the individual know that their contributions are valued by existing committers. It can also serve as a signal that lets others in the community know what committers value, thereby establishing norms. It is possible that such recognition affects contribution decisions; however interviewees generally regarded being made a committer as a welcome "pat on the back" rather than something they diligently worked to attain. Several committers mentioned cases where nominees asked not to be made committers. They also stated that many committers stopped working on the project soon after their individual needs were fulfilled and that most of those who worked on the project for fun left after a year or so.
“Most stick around for maybe 3-4 months at most, it’s okay to leave...
The ones that stay for over 6 months tend to really stay.”

- Long-term participant, open source community, Australia

**Gated Project: Character of Contributions**

As reported in an earlier section, volunteers did improve the gated product to satisfy their own needs, but rarely worked for fun or enjoyment. As a result, much necessary work does not get done by volunteers, even though that work would arguably be fun, challenging, and exciting.

Two factors, fairness and a desire for feedback, strongly affect work and contribution within the gated project\(^{105}\). More specifically, restrictions on use, modification, and distribution keep volunteers from taking on work not related to own need, because “it is only fair to be able to use what one developed.” In addition, restrictions on who can license and use the code and for what purposes limit overall use of the code and thus feedback.

“I make the changes that I really need and so does everyone else and we benefit from one another... There are a lot of things the project still needs that I keep asking [the corporate sponsor] to develop... they are not absolutely critical, but they’d take the software to the next level and expand its capabilities... if I develop it and then [the corporate sponsor]

\(^{105}\) Alternate explanations might be that the gated source software is inherently less challenging or that volunteers are relying on employees of the corporate owner to do work, however (1) the gated source project studied is generally regarded by software developers to be more exciting and revolutionary than the open source project studied. It does not appear that there is any lack of fun or challenge to be had. (2) While it is true that gated source community participants might desire that the corporate owner do as much work as possible, especially the more mundane work, this does not explain why volunteers are not seeking out the work that is (self) defined as fun and exciting.
says I can't let others see it or work on it or use it in whatever way that makes sense, now come on! That's not how it works."

- Long-term participant, gated source community, USA

"I answer questions and stuff, but I don't feel the need to contribute my changes to the community. It's time-consuming and I don't know if [the corporate sponsor] will do anything with it... At the end of the day, they make the decisions with their commercial largest licensees in mind... it's political... I just have a small business... why should they care what I need?"

- Long-term participant, gated source community, USA

"In an open source community, no one answer is forced on anyone. Everything is up for discussion and change – all the time. Sometimes it gives me a headache [chuckle]... it's empowering and it leaves room for new people to come in and make improvements and changes... That dynamic just doesn't exist in communities around tightly-licensed corporate code – or in the companies that most of us work for."

- Expert, USA
4.4.5 Achieving Community “Coordination”

How are the work efforts and products of those who contribute coordinated? The term “coordination” carries the connotation of a hierarchical (or flat) structure in which work goals are defined and tasks are carved off and assigned to individuals. This type of coordination was not observed in the communities studied, except by employees of the gated source community sponsor. Instead, participants identified tasks which they felt needed to be done and then worked on providing a solution. The mechanisms and processes that facilitated this type of “loose” coordination in the communities studied are discussed briefly below. The processes described tend to “conserve” three resources central to the community: participant time, space on mailing lists, and participant motivation.

Selected Aspects of Task Coordination

How do individuals select tasks and create boundaries around those tasks? How are tasks carried out? This section describes the role of feedback, answering questions, and joint problem solving on task definition and execution. Task coordination also involves the process by which changes and additions to be made to the source code are selected; this process requires detailed research and is not addressed here.

Feedback

Feedback from others can be used to identify areas of the code that need improvement, identify new features that users desire, or provide input on planned or completed work. There was an informal rule among developers in the open source community to “ask first and then do” so that ideas would be exposed to peer review before an individual spent his or her time executing the idea.

Community development exposes one person’s idea to critique and review by anyone interested in the issue. Those who offer opinions or ideas must be prepared to defend, and possibly alter, them106. It has been argued that this open and diverse - due to
the heterogeneity of interested participants with respect to issues such as computing environment, design skills, knowledge of the code base, and needs – peer review process contributes to the high quality of community developed code (Raymond 1999; Mockus, Fielding et al. 2000).

Two hobbyist developers who dedicated considerable amounts of time to the project pointed out that feedback sometimes comes directly from the code:

“Sometimes you work on an area and you notice that the code is getting more and more complicated – hard to understand and comprehend - say because many small changes have been made. There comes a time when you need to start from scratch and rewrite the code with all the new functionality in mind. Otherwise you look at it and get confused and everyone is less likely to be able to understand and improve that area.”

- Long-term participant, open source community, Germany

\[106\] In contrast, tactics based on power or authority might be used to influence development decisions within a firm or joint venture. Such tactics are unlikely to fare well in many open source environments and/or may inhibit community growth. Corporations interested in working with communities – and their employees – are especially aware of the difference:

“As a firm, we can’t dictate how everything works in the project and in fact, you have to go along with decisions that may not be best for you... it’s a very different development environment and I constantly have to remind my boss and colleagues of that... We can’t dictate who will do what and then. If we want a change, we have to contribute the manpower to make it happen.”

- Long-term contributor (employed to participate), open source project, USA
Providing Information

Two interesting patterns regarding information provision by participants were observed. First, participants skim mailing list headings and choose which posts to read. Most report read messages that pertain to past or current work, and occasionally look at a topic because it looks interesting or has attracted the attention of many in the community.

“The worst thing someone can do is write “question” or “help” in the subject line. You’ve irritated everyone before they even look at your question – but a few people will take a look and try to help, if you are lucky.”

- Long-term participant, open source community, USA

Second, when choosing if to respond to a question, many short-term developers respond to virtually any question they think they can answer. In contrast, the majority of more experienced participants report (1) answering only questions that they think others can not easily or accurately address, and (2) responding only when it appears that the information requestor will do work and contribute something to the community.

“I answer questions that others probably can’t answer... why spend time answering a question that someone else could take care of?”

- Long-term participant, open source community, USA

“At first I offered many opinions and suggestions. Then I learned to only respond to “how” questions.”

- Long-term participant, open source community, Germany
Joint Problem Solving

Some problems are identified, solved, and executed by a single person. Other problems are solved jointly by several people. Sending an email suggesting an idea and solution concepts attracts the interest and assistance of others.

“The more people you can attract to an issue, the better. You’ll get a good solution and that we’ll incorporate it into the source code more quickly because we can see that there’s interest and that it’s been looked over carefully.”

- Long-term participant, open source community, Germany

Selected Aspects of Behavioral Coordination

Behavioral coordination involves the enforcement of community rules and practices. The community relies on developer participation and actions that might decrease participation are punished or reprimanded (see Table 4-8 for a summary of behaviors generally deemed unfair or inappropriate behavior by communities versus firms). The community’s methods for providing punishments are limited, being generally confined to discussion, instruction, or embarrassment on mailing lists and/or not assisting a participant in the future. Four areas where behavioral coordination came up repeatedly are discussed here: software use, attainment of committer status, requests for assistance, and tone of feedback.107

Software Use

Use of the software is encouraged, but distribution of software without referencing its origins receives harsh criticism. Distribution of software without referencing its origins limits feedback – and the potential for subsequent improvement –

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107 This is not an exhaustive list.
and also appears to violate fairness norms. In one case, a developer in the open source community studied noticed that a consultant for his employer had taken a significant amount of code from the open source project, but had neglected to cite the project. He announced the consultant’s name to the open source community, as well as to his employer, colleagues, and other software developers he knew.

**Attainment of Committer Status**

As mentioned before, in the open source community studied, only those with “commit privileges” may alter the source code. Access to this privilege can be granted only by a vote from existing committers. Three positive votes are required for privileges to be granted, a single negative vote means that privileges are denied. The voting process is conservative and is likely to act in favor of preserving existing norms and practices.

**Requests for Assistance**

The projects studied had only one or two mailing lists associated with them. The positive benefit of having just one or two primary mailing list is that everyone “congregates” in one place, thereby increasing the possibility that a problem will be paired with an individual who has the knowledge to address it. The downside is that all requests for information and assistance are sent via these mailing lists, thereby increasing the volume of posts potential information providers must sort through. In order to make efficient use of the system, four informal rules for requesting information exist: (1) search the mailing list archives and FAQs before asking a question. Requests for information that is documented in the FAQs (frequently asked questions) or archives often receive a response suggesting that the individual to check these sources and not waste the time of others; (2) devise an appropriate and descriptive subject line header; (3) phrase request in an appropriate manner\(^\text{108}\); (4) send your request to the community, but copy individuals who may have expertise in the area on the email. This way, the

\(^{108}\) What constitutes acceptable behavior may differ by community. Even within the same umbrella project, participants of different subprojects behaved differently, e.g. several participants of a more supportive and low-key sub-project pointed out the more aggressive and competitive behaviors exhibited within another sub-project.
requester may get advice even if the information experts do not skim the mailing list that day.

Tone of Feedback

Positive feedback through use and critical feedback are both encouraged. Demotivating feedback (insults, blame, demands for improvements) is often met with contempt and result in a “do it yourself” messages from several developers, as illustrated by the following exchange.

Portion of Email message:

"Once again, it’s all chaos at [name of umbrella project]. I don’t understand why the folks with the capabilities and responsibilities to handle infrastructure issues and requests don’t take five minutes to set up a [tracking] category for these things. Instead, it is left to endless e-mails, no tracking, nothing gets done...."

Portion of Response 1:

"Please take note of the tone of your email. I understand your frustration, this is a volunteer organization, and while the volunteer system works well for software, it is not always great for infrastructure.

Regardless, this is where we are. You’re asking for someone to do you a "favor" and fix [problem name]. Do you feel your tone does it in a way that will motivate them to do so?

Let us now address the [tracking] issue. I've noted my preference for this as well, however, I do not currently have the bandwidth necessary to drive the discussion towards that. You, however, are empowered to do so! Join the infrastructure list and start the discussion. I would suggest that in order to be effective, you describe the problem (calmly), describe the solution, the best alternative and why you feel [solution name] would be
appropriate. Inevitably someone will argue against it or just "for" the status quo. Through persistence, offering to help manage it, etc, your issue may be addressed.

Complaining about [name of umbrella project] on this mail list will probably just peeve people off and serve you nothing, although you're certainly welcome to try it.

Is this the most judicious use of your (and others') time?

A man once said "You decide"."

Response 2:

"My response to postings like this is: Thanks for volunteering! =)"
<table>
<thead>
<tr>
<th>Table 4-8:</th>
<th>Some Collective Action Issues and Responses</th>
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<table>
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<tr>
<th></th>
<th>Employment Model in Most Firms</th>
<th>Voluntary Participation Model in Communities</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>What Constitutes Free-Riding?</strong></td>
<td>• Not producing expected work product</td>
<td>• Expecting others to undertake additional work on your behalf</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Wasting the time of others by asking questions that have been asked before or for information that will not be acted upon</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Not reporting problems experienced while using the software, esp. if such problems are likely to affect others</td>
</tr>
<tr>
<td><strong>Responses to Free-Riding</strong></td>
<td>• Individual-level incentives (may decrease cooperation between individuals and result in less information sharing and innovation)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Monitoring</td>
<td>• Specifically state that product support is not provided and should not be expected</td>
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<td></td>
<td>• Termination of employment</td>
<td>• Public or private statement explaining acceptable and non-acceptable behavior</td>
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<tr>
<td></td>
<td></td>
<td>• Being ignored</td>
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<tr>
<td></td>
<td></td>
<td>• Removal of individual’s ability to post messages to mailing list</td>
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<tr>
<td></td>
<td></td>
<td>• Automatic bug messages sent to community when problems encountered</td>
</tr>
</tbody>
</table>

| **What Constitutes Theft?** | • Using firm resources for personal benefit |
|                          | • Appropriation of proprietary information or equipment |
|                          | • Not referencing the community as the source of all or part of the code |

| **Responses to Theft** | • Legal action |
|                       | • Termination of employment |
|                       | • Harsh public statement condemning action and reporting the individual’s name |
|                       | • Legal ownership of code by the collective, which may threaten to enforce property rights (never done before) |
Section 4.5: Discussion

This section examines two issues in detail: (1) the ways in which the concept of fairness influences community participation and (2) the process by which contributions are assessed, selected, and incorporated into the code.

4.5.1 Fairness: Responses to Contribution & Governance

Fairness appears to strongly influence community participation in (at least) two ways. First, individuals must choose whether or not to contribute their knowledge. Second, individuals must choose the extent of their community involvement. These issues are discussed in the following two paragraphs.

Many short-term participants and a few long-term participants said they contributed primarily because they thought it was the appropriate thing to do within the community. The observation of activity on the mailing lists, as well as help they themselves had received in the past appear to have promoted this perception. Two processes may be at work: (a) A social facilitation effect whereby observing the contributions of others leads one to contribute as well. Kollock discusses the impact of this process in the context of open source software development and the recruitment of volunteers for public service work (wiring public school classrooms) over the Internet (Kollock 1999); (b) Repaying the community for help one had previously received. In the context of software development communities, such repayment, or reciprocity, has two interesting characteristics. First, it takes the form of generalized exchange, because individuals contribute what they know to whoever needs it, not just the person(s) who provided them with assistance. This is likely to occur when knowledge is being exchanged, since there is no guarantee that the assistance you can provide will be of use to the person who provided you with assistance. Second, because of the public nature of the exchange, contributions are shared with the entire community. This increases the information set from which an individual in the community can draw upon and helps the
community as a whole progress. Such public exchange is not limited to the software community or the Internet, and is likely to be widespread among amateur hobbyists\textsuperscript{109}. Community participants must also make decisions regarding the extent of their involvement within a particular community. Community (institutional) rules and processes deeply impact an individual’s decision whether or not to create or “play with” the software beyond what their own needs require. The developers interviewed expected continued access to software they had helped develop and the ability to use that software in whatever context they wished. The licensing structure of the open source software project met both of these requirements. The gated software did not. The effect was three-fold. First, many gated project participants reported that they used the gated software only after other options had been exhausted and found unsatisfactory\textsuperscript{110}. This decreases the size of the community and thus the volume of activity that takes place within it. Second, many gated source community participants – especially those not affiliated with large corporations on good terms with the corporate owner - felt uneasy with the software and how software-related decisions would be made. They felt a need to make sure their voices were being heard and their interests were being represented. Third, individuals rarely worked on the gated-source project to satisfy anything but their most pressing needs. This decreases both the volume and scope of work undertaken by volunteers\textsuperscript{111}.  

\textsuperscript{109} Skateboarders and other sports enthusiasts have created websites directing others on how to do the latest tricks or improve their equipment. Newsletters and magazines were created to facilitate information exchange between innovative amateur automobile enthusiasts in the early 1900s and innovative sports enthusiasts in the late 1900s (Franz 1999; Shah 2000). Ham radio operators in the mid-1900s, responsible for several commercially important technological developments in electronic components, communicated via newsletters and radio waves (Haring 2002).  

\textsuperscript{110} They found the licensing structure unfair, especially since they would be required to do a considerable amount of the work necessary to make the software useable. Moreover, the licensing terms made corporate legal departments uneasy and added another barrier to use that had to be overcome. Gated participants who worked for large corporations, especially those with an existing relationship with the corporate owner of the gated software, had an advantage in that they were more readily able to negotiate licensing terms for commercial use.  

\textsuperscript{111} In a sense, developers who might have worked on the software for fun are not participating at cost to themselves (Kahneman, Knetsch et al. 1986b).
If the software is very much needed, that is it provides truly unique and useful functionality for some users (enough so that those users are willing to contribute to its development) and a corporate owner is willing to hire employees to do some of this work, the effect of the first and third issues may be partially overcome. Decreased participation and general mistrust of the fairness of the process, however, are likely to continue and to affect both the character and volume of participation. In this paper, one element of the licensing structure – open source vs. gated source – was examined, however other elements of the community governance structure may also play a role in affecting the extent of an individual’s involvement.

4.5.2 How Do Communities Turn “Ad Hoc” Contributions Into High Quality Products?

Many processes contribute to the creation of high-quality products in communities. Three are of critical interest: the ability to build upon and use the work of others, feedback, and the presence of hobbyists. The open and often public nature of exchanges, as well as electronic or paper documentation of past exchanges, allows everyone access to information and build upon it. Free use and distribution of the product is critical. When use and distribution are restricted, as in the gated source community studied, individuals generally did not create or contribute anything more than that required for their own use. Positive and negative feedback serve, respectively, to encourage creation and contribution, and guide improvements and future work.

The presence of hobbyists who care about product design is critical to the community. Their presence increases the likelihood that the code will remain of high quality on a number of dimensions (e.g. modularity, compactness, simplicity), thereby making the code accessible to new users who seek to understand and improve parts of the code. In contrast, individuals who are motivated only by need might create the new

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112 The community would be without the “need”-neutral voices of those who participate as a hobby and prevent the code from becoming too large or too messy or incorporating too many features. It is unlikely that such individuals are “selected out” of the community from the onset since they are likely to have the same distribution of software needs as others; they probably enter the community and only work to satisfy their own needs, and spend their discretionary “hobby” time on other projects. There is some evidence of this in the sample.
feature and "tack it on" to a part of the code. Successive additions of this kind are likely to result in code that is large, difficult to understand and improve, and suffers from problems due to interactions between areas of code\textsuperscript{113}.

\textbf{Section 4.6: Model}

A model that explains technical progress in user communities must address why individual developers choose to create within and contribute to the community, as well as how developers overcome technical and knowledge barriers and how contributions are transformed into high-quality products, with a sustainable architecture. The model outlined below was derived inductively.

\textbf{4.6.1 Need Drives Initial Participation}

The primary driver of initial participation – both creating and contributing – is the need for changes or alterations to the product. Participants initially search for existing solutions to their problems, and only if no solution is found do they create one on their own or with the assistance of others\textsuperscript{114}. Because a need exists, many individuals do not wait for others to solve the problem.

Some of these individuals contribute the solution back to the community, others do not. A desire for improvements on their work leads some to contribute. These individuals continue to monitor the mailing lists for discussion regarding their needs and often help others working in the same area. Unless an individual believes she has the "best" solution, she is likely to contribute in order to benefit from potential improvements to the idea by others. Some report that they contribute back because "it seems like the right thing to do." They often contribute; however, they often also exit the community.

\textsuperscript{113} The process of writing an academic paper is analogous. If one writes a paper and asks several friends to comment on it and then merely "add in" each individual's comments, the paper will likely be a mess. Instead, the comments must be understood, selected, and carefully integrated into the paper; and portions of the paper may have to be completely rewritten.

\textsuperscript{114} Assistance may be requested from community participants (in open source communities, communication occurs primarily via mailing lists) or others who the individual knows (e.g. co-workers at their day job).
soon after their needs are met\textsuperscript{115}. The amount of assistance received from others appears to increase the likelihood of contributing something back.

4.6.2 Reasons for Participation Change Over Time

An individual’s reasons for participating may change over time (Figure 4-1). Need may initially lead the developer to the community. However as the individual gathers information and learns more about the code in order to solve his or her problem, he or she may find other problems of technical interest in the same or other areas of the code\textsuperscript{116}. Gelerntner and others discuss the beauty of code and the psychological pleasures that can be derived from interacting with it (Weizenbaum 1976; Gelernter 1998).

"... almost any project will give a developer that “feel good” feeling when he has users and he feels he is doing something worthwhile. I really don’t think you need all that much “quid pro quo” in programming – most of the good programmers do programming not because they expect to get paid or get adulation from the public, but because it is fun to program."

- Linus Torvalds (Torvalds 1998)

In the case of open source participation, developers find such problems as they scan through the mailing lists looking for information related to current interests. A particular subject line might catch their interest and prompt them to read the message. This may result in investigation of the related code and participation in related work. Over time, the individual learns more about the structure and architecture of the project’s code base, increasing the individual’s knowledge base and ability to manipulate and improve the code.

\textsuperscript{115} In a sense, these developers have decided that the existing solution is “enough” for their problem – or lack the time or desire to seek an improved solution.

\textsuperscript{116} This is in line with the empirical observation that open source software developers often specialize in one or two areas of the code. (von Krough and Spath 2003)
FIGURE 4-1:
EVOLUTION OF PRIMARY MOTIVES OVER TIME

Need for Improved Product

Check Archives, Monitor Mailing Lists, Examine Code

Learn more about code in area of interest, potentially finding solution to need and possibly contributing
Find problems of (technical) interest in same or other areas of code

Begin participating for fun; Gradually increase knowledge of code architecture
4.6.3 Enjoyment & Personal Satisfaction Drive Many Long-Term Developers

A subset of those who participate for an extended period of time, do so primarily because they enjoy programming and open source projects are a venue in which they can choose the programming activities they engage in and get feedback on their work (Table 4-9). Participation is often viewed as a hobby. Contribution of the code is necessary to obtain feedback.

Feedback enhances intrinsic motivation in certain situations\textsuperscript{117}. Positive feedback in these communities occurs via two channels: use and occasional commentary on the code by others (generally those with an interest in code structure and architecture). Feedback often creates additional work, primarily responding to bug reports and assisting others who are working on issues related to the code you wrote. Developers appear receptive to this type of work, since it often creates interesting puzzles for them to solve; in fact, many report monitoring the mailing lists for discussions related to what they wrote.

"So the large user-base has actually been a larger bonus than the developer base, although both are obviously needed to create the system... I simply had no idea what features people would want to have, and if I had continued to do Linux on my own it would have been a much less interesting and complete system... the thing is that a Linux user has a very hard time not giving things back. He doesn't have to give anything back actively: it is feedback to just know that some person uses Linux for a certain application domain. And usually even a very silent user tells a lot more than that – just by the type of questions he posts to newsgroups and mailing lists."

- Linus Torvalds (Torvalds 1998)

\textsuperscript{117} Cognitive evaluation theory argues that intrinsic motivation is based on feelings of competence and self-determination - and that external constraints, such as contingent rewards, often influence these feelings based on their "informational" and "controlling" characteristics (Deci 1975). External informational characteristics provide feedback about competence and can either enhance or detract from intrinsic motivation depending on content. Substantial empirical evidence supporting cognitive evaluation theory exists (Deci 1971; Lepper and Greene 1978; Boggiano and Pittman 1992).
These developers are often interested in technical problems, although their interests vary widely. Because they have already satisfied their own immediate software needs, they have an understanding of some area of the product and make further modifications based on the needs and ideas of others, or partake in work that they deem necessary to improve the software's capabilities or design (architecture). Attention to technical detail is important to this, often small, subset of developers. They are generally interested in striking a balance between usability (and number of standard features) and keeping the code simple, elegant, and easy to understand. The latter allows developers to independently make whatever changes they require and precludes the need for voluminous documentation.

These same developers appear to avoid "managing" the project. Most posts containing an introduction and a request to be assigned a task are either ignored or the requestor is told to monitor the mailing lists. Individuals interested primarily in reputation or status building must first find a niche that interests them and where they have the skills to be useful. This can be a time-consuming and frustrating exercise. While some or many may attempt it, the developer who participates and engages in the community without a specific need is rare. This is in stark contrast to the management process in most firms where a project manager assigns tasks (Table 4-10). The practice of turning away such requests and making potential participants find and solve their own problems effectively creates a screening mechanism whereby only those with skill, time, and desire to program become a short- or long-term part of the community.

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118 In a sense, the developers appear to shun any work that does not focus on the code itself and their preferences for such "pure" work appear to be in line with Abbott's conception of professional purity: "by professional purity I mean the ability to exclude non-professional issues or irrelevant professional issues from practice... the highest status professionals are those who deal with issues predigested and predefined by a number of colleagues. These colleagues have removed human complexity and difficulty to leave a problem at least professionally defined, although possibly still difficult to solve (Abbott 1981, p. 823)."
<table>
<thead>
<tr>
<th>Reason to Create</th>
<th>Reason to Contribute</th>
<th>Relative Level of Individual Participation</th>
<th>Relative Number of Participants</th>
<th>Knowledge of Code Structure (“Learning”)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Need</td>
<td>Future product improvements</td>
<td>Varies, depends on need</td>
<td>High</td>
<td>Primarily in area of initial problem, may expand slightly</td>
</tr>
<tr>
<td>Fairness</td>
<td>Low</td>
<td>High</td>
<td></td>
<td>Limited to area of initial problem</td>
</tr>
<tr>
<td>Fun, Enjoyment</td>
<td>Feedback</td>
<td>High</td>
<td>Low</td>
<td>Initially area of initial problem, gradually broadens</td>
</tr>
<tr>
<td>Reputation</td>
<td>Reputation-Related Benefits</td>
<td>Low(^a)</td>
<td>Very low</td>
<td>Difficult to begin; difficult to find a “niche”</td>
</tr>
</tbody>
</table>

\(^a\) Two primary exceptions exist: some individuals interested in building a reputation choose to do documentation work; others may find an initial area to work on based on matching their existing knowledge of some area of software development with a question or suggestion posed by another individual.
<table>
<thead>
<tr>
<th></th>
<th>Employment Model in Most Firms</th>
<th>Voluntary Participation Model in Communities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Who can Participate?</td>
<td>● Employees are screened and selected</td>
<td>● Anyone</td>
</tr>
<tr>
<td>Primary Motives for Initial Involvement</td>
<td>● Money and employment benefits</td>
<td>● Need for product or product feature</td>
</tr>
<tr>
<td>Primary Motives for Extended Involvement</td>
<td>● Money, employment benefits, power</td>
<td>● Need for product or feature</td>
</tr>
<tr>
<td></td>
<td></td>
<td>● Fun, Challenge</td>
</tr>
<tr>
<td>Tasks Undertaken</td>
<td>● Most often assigned and monitored by managers or owners</td>
<td>● Related to own needs</td>
</tr>
<tr>
<td></td>
<td></td>
<td>● Varied: can include maintenance of product and organization</td>
</tr>
<tr>
<td></td>
<td></td>
<td>● Chosen by participants and undertaken voluntarily</td>
</tr>
<tr>
<td>Primary Exchange Concepts</td>
<td>● Employee-firm (owner, manager): economic exchange</td>
<td>● Social exchange</td>
</tr>
<tr>
<td></td>
<td>● Between employees of similar position: social exchange</td>
<td>● One to many (or public) communication whenever possible (individual – community and individual-individual both occur simultaneously on mailing lists)</td>
</tr>
<tr>
<td>Authority and Control</td>
<td>● Owners and managers</td>
<td>● Distributed among individuals</td>
</tr>
<tr>
<td></td>
<td></td>
<td>● Some communities have formal heads - most try to assert as little control as possible</td>
</tr>
</tbody>
</table>
Section 4.7: Conclusion

Hobbyist hackers who work for free are not new to the computer industry, as illustrated in the following quote:

“In the late 1960s, just outside Seattle, a group of teenagers met after school each day and biked to a local company. As it closed for the day and its employees began heading home, the boys were just getting started. They routinely thought of themselves as the firm’s unofficial night shift, and in fact they routinely worked until long after dark, pounding on the keys of the company’s DEC computer and gorging on carry-out pizza and soft drinks. The two leaders of the group [Paul Allen and Bill Gates] were considered a little odd by their classmates. They were “computer nuts,” completely absorbed in the technology. All the boys worked for free... Computer Center Corporation, which they called “C Cubed” let them come in to find errors in the DEC computer’s language... as long as C Cubed could show that DEC’s program had bugs (errors that caused the programs to malfunction or “crash”), the firm didn’t have to pay DEC for using the computer (Freiberger and Swaine 2000).”

Although there are many reasons why an individual might participate in a product development community, a need for the software and enjoyment lead the list. Hobbyist developers are critical to the functioning of a voluntary software community. They take care of many maintenance needs and oversee the overall code design from a relatively neutral perspective. A large set of users and developers, each with their own set of needs and agenda, are necessary to generate a variety of ideas and solutions from which those that offer valuable functionality can be chosen. Communication between developers and users of the software is critical and a software community is likely to flourish only when anyone can enter and when each participant feels empowered to do as much or as little as he or she desires. Limiting participants’ ability to alter and use the code through any one of a variety of formal or informal mechanisms is likely to decrease participation and may either drive hobbyists away or lead them to change the nature of their activities.
There are several limitations to be considered when interpreting and using the results of this study. The study takes an in-depth look at two of the many software development communities that exist today. Studies of additional communities, large and small, are needed. Additional empirical is needed to further investigate the linkages between an individual’s motivations and types of contributions he or she makes, especially among the many participants who each contribute only a little, but in aggregate contribute a great deal. Finally, the software developed in both projects mentioned here is generally used by developers working within corporations. Software developers participating in other projects might have different individual characteristics (e.g. age, education level) and motivations for creating and contributing. For example one might expect learning or ideology to be a more common “cause” among college students or observe that groups of developers motivated primarily by ideology are most likely to create software that substitutes for equivalent proprietary software\textsuperscript{119}.

Interesting areas for future research involving community-based innovation and product development include: \textit{Problem Domain}: In what problem domains are we likely to see or not see communities emerge? \textit{Governance}: What governance mechanisms are likely to increase or decrease active participation? \textit{Community Creation}: How are communities started? What variables impact their early growth? \textit{Status and time}: How will the status structures created naturally affect community evolution over time? What are the ramifications of individual efforts to achieve high-status? \textit{Selection of Problems and Solution Concepts}: Once problems have been identified and potential solutions contributed, how do committers choose what to incorporate and what not to incorporate into the code? Design issues and feedback from the community regarding what is useful and not useful play a role, but more detailed work is needed. \textit{Corporate Participation}: How will communities react as corporations begin to see and use communities for their own strategic ends? What will be the effect on product development?

\textsuperscript{119} One would still expect that a substantial portion of the work done in such communities would still be done by people who enjoy developing software. After all, there are many other ways to express ideology or build reputation besides spending hours writing software code.
Appendix

What Is Open Source Software Development?

There are many definitions of what constitutes open source. The basic idea is simple: by making the source code for a piece of software available to all, any programmer can modify the software to better suit his or her needs and redistribute the improved version to others\footnote{The formal Open Source Definition can be found at: http://www.opensource.org/docs/definition.html}. By working together, a community of both users and developers can improve the functionality and quality of the software. To be open source requires that anyone can get and modify the source code, and that they can freely distribute any derived works they create from it. The different licenses have various wrinkles on whether modifications must also be made into open source or if they can be kept proprietary (Gabriel and Goldman 2001, entire paragraph).

How Are Open and Gated Source Development Different From Other Methods of Producing Software?

Software development methods can roughly be characterized as either proprietary or community-based (Figure 4-2). Proprietary software is often owned and developed by a corporation. The corporation sells binary code to users of the software (consumers), who then install and run the binary code on their computers\footnote{Individual purchasers of software as well as firms who contract with software design companies for specific products often receive binary code as an end-product. In the latter case, contractual arrangements are often made to hold the source code in “escrow” should the purchasing company need it in certain situations.}. Binary code is made up of a series of 0’s and 1’s and can be understood by a computer, but not by an individual. If a user finds a problem with the software or has an idea for a new product feature, he or she must request the change from the company who sold them the software.

Community-based software can either be owned by a firm or by another actor. However, the source code, not the binary code, is distributed to users. The source code is software code written in a particular programming language. Anyone with knowledge of the language can understand and alter the software. The user converts the source code into binary code and runs it on his or her computer. Should the user want to make a
change to the software, he or she can change the source code, convert it to binary, and then run it on the computer. The user can then tell others about the modifications he or she has made. While only company software engineers have the ability to change proprietary code, many individuals have the ability to change community based code.

There are two general approaches to community-based software development: gated development and open source development (Figure 4-3). Both seek to attract volunteer developers, but take different approaches to licensing and community governance. Gated development is the more restrictive of the two, and limitations on who can view, use, modify, and distribute the code may be specified by the owner of the code.
**Historical Roots of Open Source Software Development**

Open source and community based software development are not new concepts, they are as or nearly as old as the history of computing. The historical antecedents of what we now call “open source” can be seen in the development histories of the early IBM 360 Systems, the Unix operating system, and much of the software developed in university labs in the 1960s and 1970s\(^{122}\) (Bashe, Johnson et al. 1986; Salus 1994). Using a community to develop and share software made sense as a practical matter and does not appear to have been promoted as a philosophical matter.

In 1984 Richard Stallman formed the free software foundation and started the GNU project (http://www.gnu.org). He did so in response to seeing the collapse of the software-sharing community at the MIT Artificial Intelligence Lab as many left to join companies making proprietary software. Stallman coined the term *free software* to express his philosophy that programmers should be allowed access to the source code so they could modify it to suit their needs.

> “I consider that the golden rule requires that if I like a program I must share it with other people who like it. I cannot in good conscience sign a nondisclosure agreement or a software license agreement.”

- Richard Stallman, 1983,

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\(^{122}\) There is a long history of software code written in the OS tradition; much of which directly or indirectly benefited firms and certainly benefited society as a whole. For example, early open source communities were critical to the development of early IBM software (Pugh, Johnson et al. 1991). IBM managers were conscious of and strategic in their decision to encourage customers of their hardware products to share software and software related information. This practice effectively increased the value of IBM hardware to the customer, while requiring less time and investment by IBM than if they had tried to investigate and satisfy customer needs independently. In contrast, early prototypes of the Unix operating system were a stepchild project at Bell Labs (Salus 1994). However, project engineers promoted Unix outside of Bell Labs and encouraged others (outside of Bell Labs) to continue development (Salus 1994); allowing others the ability to contribute to the project fueled its development and kept it alive.
He developed the GNU General Public License (GPL) to assure that he would always be able to see and modify the source code for any software he wrote, along with the modifications made by anyone else who might work on it (Gabriel and Goldman 2001).

Further details on the history of open source are available on-line and in books like *Open Sources: Voices from the Open Source Revolution* (edited by Chris DiBona, Sam Ockman and Mark Stone) and *Rebel Code: Inside Linux and the Open Source Revolution* by Glyn Moody.
FIGURE 4-2: PROPRIETARY VERSUS COMMUNITY SOFTWARE DEVELOPMENT

- Scheduled releases
- Work done and decisions made by paid employees and project managers

- Frequent releases
- Extensive involvement by many

FIGURE 4-3: TWO APPROACHES TO COMMUNITY SOFTWARE DEVELOPMENT

<table>
<thead>
<tr>
<th></th>
<th>Gated</th>
<th>Open Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Who can use?</td>
<td>Those who agree to license; commercial use may require royalty payment</td>
<td>Anyone</td>
</tr>
<tr>
<td>Who can modify?</td>
<td>Only licensees</td>
<td>Anyone</td>
</tr>
<tr>
<td>Who can you share?</td>
<td>Only other licensees</td>
<td>Anyone</td>
</tr>
<tr>
<td>Who owns?</td>
<td>“Sponsor” retains rights to code (and improvements)</td>
<td>“Owned” by the collective</td>
</tr>
<tr>
<td>Who manages and makes decisions?</td>
<td>“Sponsor” stipulates and delegates project decisions</td>
<td>Users or “benign dictator”</td>
</tr>
<tr>
<td>Example licenses</td>
<td>SCSL</td>
<td>GPL, BSD, ASL</td>
</tr>
</tbody>
</table>

*Both seek to attract volunteer software developers*
BIBLIOGRAPHY


*Numerous web sites and sport-specific magazines and newsletters were also used*