9 Creating a Context for Entrepreneurship: Examining How Users' Technological and Organizational Innovations Set the Stage for Entrepreneurial Activity

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I. Introduction

It is widely acknowledged that innovation and entrepreneurship drive economic growth and prosperity. But, what drives entrepreneurs? This question is of critical interest to political and business leaders and of scholarly interest to a wide variety of academic disciplines. Start-ups contribute to the health of our economy and society by creating jobs and by providing access to technologies—both novel and established—to those who need and want them. The provision of innovative products and services improves the day-to-day lives of many consumers and citizens.

At the same time, innovation and entrepreneurship are also complex, challenging, and knowledge-intensive activities. The process by which innovative new products and services are developed involves novel insights and considerable learning about technologies and markets (Taylor 2010; Clark & Fujimoto 1991; Brown & Eisenhardt 1995). Hence, from the perspective of the external observer and possibly from the perspective of the entrepreneur, undertaking these activities appears to involve considerable risk, effort, and time.

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So, how then do potential entrepreneurs make the decision to commercialize an innovative product or service? Most prior examinations of entrepreneurship have focused on fairly *static* factors. These static factors can be either internal to the entrepreneur (e.g., intrinsic attraction to risk) or present in the entrepreneur's environment (e.g., "culture"). While we acknowledge that such factors play a role in entrepreneurial activity—for example, some individuals are predisposed to entrepreneurial activity, have cognitive traits that help them become successful entrepreneurs, or are situated in environments rife with resources—static approaches ignore the circumstances in which entrepreneurs are *made*, and in which entrepreneurial individuals are coproduced with the environment that supports them. The lesson we illustrate, through our data, is that entrepreneurs are made through a series of interactions with an external and changing environment. Building upon the seminal argument in both classic and contemporary sociology that individuals shape and are shaped by their social context, we show how these interactions affect both the environment and the potential entrepreneur, culminating in entrepreneurship (Giddens 1984; Weber 1904; Coleman 1994).

We illustrate this point by examining the experiences of user entrepreneurs. User entrepreneurs are individuals whose experiences creating or modifying a technology that they themselves used—often combined with their experiences creating and/or participating in a community of other users coalesced to further develop and diffuse the technology—steered them toward founding firms dedicated to commercializing their innovation(s). User entrepreneurs have played pivotal roles in many economically important industries: serving as a source of technological insights to established firms (Winston Smith & Shah 2013), introducing new innovations into established industries (Shah & Tripsas 2007; Baldwin, Hiernerth, & von Hippel 2006), creating technological discontinuities in established industries (Tripsas 2008; Haefliger, Jäger, & von Krogh 2010), and founding the first—or among the first—and often the most successful firms in a new industry (Shah & Mody 2013). Almost 50 percent of firms founded in the Unites States to produce an innovative product or service that survive to age 5 are founded by user innovators (Shah, Winston Smith, & Reedy 2012).[1]

Throughout this chapter, we will supply examples of user entrepreneurship from both high-tech (e.g., biotechnology and microelectronics) and low-tech (e.g., juvenile products) industries. This extensive data, culled from studies in the innovation and history of technology literatures, supplements an intensive examination of two industries: scientific instrumentation, specifically probe microscopes; and sporting equipment, specifically windsurfing boards. We gathered data on probe microscopy and windsurfing through more than two hundred interviews with users and examination of archival materials and published sources generated by or about these user communities.[2]

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[1] A full 10% of all entrepreneurial start-ups founded in the United States that survive to age 5 are founded by user innovators.

[2] Readers interested in further details of our methodology are referred to our previous work on the role of users in the development of technology and organization in probe microscopy and sporting equipment (Mody 2011; Shah & Mody 2013).

This chapter contributes to entrepreneurship theory by showing how individuals' entrepreneurial proclivities co-evolve with the technology and organizations created to sustain that technology. We build on the insight that users engage in technological innovation and innovation in organizational forms concurrently: technological innovation allows users to create the equipment and techniques that allow them to shape and tame their external environment, whereas organizational innovations allow users to build new and extend existing institutions such that their technological innovations can flourish (Shah & Mody 2013).

This chapter also contributes to our understanding of the role of a particular type of knowledge commons—a user innovation community—in stimulating entrepreneurship and technological development. We show how the interactions that occur in the commons generate information, resources, skills, and affective rewards that contribute to entrepreneurial activities, while maintaining the integrity and stability of the commons.

Finally, in keeping with the theme of this edited volume, we use empirical data to highlight unique characteristics of a particular type of knowledge commons, namely innovation communities constructed by users, as part of an effort to bring nuanced data to bear upon the task of understanding the role, governance, and functioning of knowledge commons. As Madison, Frischmann, and Strandburg point out, the "devil is in the details": adapting Ostrom's Institutional Analysis and Development framework to investigate sharing and resource-pooling arrangements for information- and knowledge-based works will require "significant modifications" (Madison, Frischmann, & Strandburg 2010: 670–71).

One such modification may involve envisioning knowledge commons as means to an end, rather than an end goal or sustaining organizational structure in and of itself. The seminal work of Elinor Ostrom and colleagues views the commons as a means of sustaining natural resources (Ostrom 1990).[3] In the two cases highlighted in this chapter, the user innovation community (a specific type of knowledge commons) is constructed as a means through which technologies can be developed and diffused. However, as users' needs evolve, additional proprietary organizing structures—network exchanges and industries—that draw from and sometimes contribute to the knowledge produced and held within the commons are also built by users. This illustrates the notion that commons-based organizing structures can play a critical role in a technology's development and diffusion, but other organizing structures may be equally necessary and provide the means for developing and diffusing a technology to meet the needs of distinct types of users. A second modification may involve further grappling with the nonrivalrous character of knowledge and the purposive transfer of that knowledge outside the

[3] We see no contradiction in actors' interpreting cultural commons as both means and ends simultaneously. For instance, we have interviewed many people who were members of user innovation communities partly out of enjoyment of the relationships and activities fostered by the community (commons as an end) and partly as a way to access resources needed to improve a technology that they intended to use (commons as a means).

commons. Whereas the natural resource commons exist to sustain a resource for the use of a circumscribed set of individuals, many cultural artifacts may be developed within a commons, and later diffused broadly to many through a variety of means. In this chapter, we focus on the role of entrepreneurs and new firms in diffusing a rapidly evolving technology; however, we also acknowledge that diffusion is aided by established firms, private and public universities, privately owned media outlets, and so on. We hope that the cases highlighted here, combined with the other examples highlighted in the volume, serve to provide nuanced and contextualized empirical data that will allow scholars to further develop our understanding of knowledge commons.

We begin by providing a brief review of the literature on entrepreneurial motivation. We then describe the innovative activities of users, highlighting the fact that users create new innovations and new organizations. In fact, it appears that technologies and organizations co-evolve, and—in cases where users create altogether new technologies—are coproduced.

Finally, we show how these activities set the stage for entrepreneurship. We focus on how sharing and collaborative work practices increase the availability of information, expand the set of individuals using the technology, and introduce affective rewards and skill growth that can pave the way to entrepreneurship.

II. Why Do Individuals Engage in Entrepreneurship? Insights from the Existing Literature

We bring an interdisciplinary perspective to our work, as we have training in management studies, engineering, and science and technology studies. We believe that the question of entrepreneurs' motivations lends itself to interdisciplinary investigation, since the problem combines (at the very least) dynamics at the level of individual psychology, organizational capacity, and economic decision making. In this section we briefly review some of the approaches that have informed ours.

A. Psychology

Much popular and political discourse depicts entrepreneurs in psychologistic terms, whether as go-getting "risk-takers" or, more darkly, as norm-defying "psychopaths."[4] Many academic studies have also taken individual cognition as the primary factor in explaining entrepreneurship. Researchers in psychology and, increasingly, neuroscience and genetics have claimed that entrepreneurs possess intrinsic—even, biologically inherited and therefore congenital—traits that predispose them to found firms: intelligence,

[4] For the former, see Brockhaus & Horowitz (1986). For the latter, see Ronson (2011); Babiak, Neumann, & Hare (2010).

a capacity to recognize opportunities, openness to new experiences, and both a greater propensity to take risks and less anxiety when confronting risks.[5]

B. Business History

Unfortunately for psychologistic explanations, levels of firm formation appear, at least at first glance, to have varied quite widely over time and across regions. If entrepreneurs are born, not made, it is not clear why so many of them would have been born in late eighteenth and early nineteenth century Manchester and Sheffield rather than in Bath or Bristol during the same era (Misa 2011; Becattini 2004; Marshall 1919). Spatially- and temporally-delimited phenomena are ready-made for historical analysis, and business historians have repeatedly examined and debated the reasons why some regions have become entrepreneurial hot spots.

In general, business historians have depicted the motivations for entrepreneurship as emergent from a national or community-level environment external to the entrepreneur. However, how such larger social formations influence entrepreneurship is unclear. One prominent, if now rather dated, view was that "culture" could largely account for why inhabitants of one region were more likely to found firms than inhabitants of another region (Landes 1999).[6] That is, some cultures were said to be more encouraging of risk-taking, more tolerant of failure, and more approving of material gain, while others were said to be more inhospitable to individual undertaking.

Cultural explanations have been roundly criticized for their superficial and reifying characterizations of whole societies or communities and for their inability to specify exactly what culture is. Such studies have, therefore, steadily lost favor in business history and have been replaced by accounts that pay closer attention to concrete phenomena. In particular, many recent studies have examined the role of institutions (such as banking systems or legal regimes) and social networks (e.g., among coreligionists or members of diasporic ethnic communities[7] or colocated artisans) that stimulate firm formation by providing entrepreneurs access to markets, expertise, and resources.

C. Geography and Regional Development Economics

Many of the same themes have also been taken up by geographers and regional development economists. While some prominent works in this literature have fallen back on

[5] For an overview of the psychologistic approach to entrepreneurship in which cognitive traits are ascribed to genetic predisposition, see Nicolaou & Shane (2011).

[6] Note that Landes has been making similar arguments since the 1940s and that his views are still influential enough to have been cited in recent speeches by Mitt Romney. The culture thesis has also been pursued in work such as Weiner (1981) and Morris (1967). For an updated version of this argument, somewhat more compatible with our own perspective, see Godley (2001) and Tsang (2006).

[7] E.g., Louri & Minoglou (1997); Dobbin (1996); Kirby (1993); McCabe, Harlaftis, & Minoglou (2005).

rather obscure cultural factors fostering entrepreneurship (e.g., the stimulating role of the "creative class"[8]), much work in this field has been admirably detailed in examining how institutions, ancillary firms, and social networks lower the barriers to entrepreneurship in industrial districts such as Silicon Valley.[9] Individuals who live in a region where there are already many other entrepreneurs have many models to follow if they wish to found a firm themselves, and they have access to local banks, lawyers, public relations firms, universities, and so forth that are used to dealing with entrepreneurs and provide valuable resources.

D. Management

Management scholars have built upon and further explored many of the themes previously mentioned. In addition, the institutional approach to entrepreneurship is gaining traction. This is a relatively new approach, built atop institutional theory. Institutional theory has long been criticized for not providing a role for agency (DiMaggio 1988). In response, recent research has studied individuals who transform existing institutions, referring to these individuals as "institutional entrepreneurs" (Garud & Karnøe 2001; Greenwood, Suddaby, & Hinings 2002). However, until quite recently, institutional theorists have paid far less attention to entrepreneurship in the sense of founding and managing new organizations (Sine & David 2010). This approach to entrepreneurship focuses on how existing institutions shape entrepreneurial opportunities and actions, how entrepreneurs navigate the environments that surround them, and how entrepreneurs modify and build institutions to support new types of organizations. This approach has been credited for its theoretical flexibility in that it does not constrain or put boundary conditions on the rationality of actors, specific historical context, or level of analysis (Thornton 1999). In particular, early work by Van de Ven and Garud has examined how the actions of entrepreneurs have both built firms and shaped the institutions around them; in turn, these institutions provide the infrastructure upon which firms build (Van de Ven & Garud 1993).

Each of these perspectives contributes to our understanding of entrepreneurship. Studies in business history, geography and regional development economics, and management all point to the importance of resources in stimulating and supporting entrepreneurship. Hence, studies of entrepreneurs' interactions with social networks (defined by ethnicity, trade, or region), ancillary organizations (e.g., universities or business groups), and institutions (such as the patent system, financial regulations, and social movements) all inform our understanding of how to help new ventures be successful. However, it

[8] E.g., Florida (2005). In a broadly similar, though less reductive, vein are Saxenian (1996) and Castells & Hall (1994).

[9] See especially the essays in Kenney (2000). Organizational sociologists have also offered similar explanations for the development of entrepreneurial clusters (e.g., Owen-Smith & Powell 2004).

appears unlikely that such resources alone are enough to spark the types of high-growth entrepreneurship that many regions desire.[10]

It should be obvious that one of the most important components of the external environment with which potential entrepreneurs must interact before deciding to found a firm is the good or service that they intend their firm to sell. While there are important exceptions, familiarity with the artifact being sold would seem to be as necessary a precondition for entrepreneurship as any cognitive trait or external resource, and it would seem to offer an advantage in leveraging other factors in the entrepreneur's environment. For example, banks, venture capitalists, and social networks may be reluctant to offer money, trust, and access to a variety of resources unless the entrepreneur can demonstrate that she is familiar with the artifact she intends to sell. A vibrant set of studies in economics and management shows that firms founded by entrepreneurs possessing prior experience in a particular industry tend to survive longer than other firms (Klepper & Simons 2000; Helfat & Lieberman 2002; Agarwal et al. 2004).

But what about situations in which the entrepreneur intends to sell a technology or innovation that is so new that it is not currently on the market? In such cases, how can a nascent entrepreneur gain enough familiarity with the innovation to see its market potential and understand how to make and sell it? The answer, surprisingly often, is that prior to founding a firm, the entrepreneur was a user of the premarket version of the innovation and usually also a user innovator.

III. What Do Users Create? Technologies, Social Structures, and Firms

User innovators are distinguished from other innovators by the motives that drive their innovative activities: users innovate because they expect to benefit by *using* the innovations that they develop (von Hippel 1988). In contrast, manufacturers expect to benefit from an innovation by selling it to others. Users have been responsible for key innovations across an astonishing array of "high" and "low" tech, physical and virtual, and industrial and consumer product categories, including medical devices, scientific instruments, semiconductors, software, and sports equipment (von Hippel 1988). Innovative communities of users of one technology have, historically, also been important seedbeds of entrepreneurship in related technologies: ham radio enthusiasts, for instance, were important contributors to the early vacuum tube and personal computer industries (Haring 2007). The Wright brothers invented the airplane partly on the basis of know-how developed from their participation in the bicycle enthusiast community. With the proliferation of new information technologies and the decline of in-house corporate research units since the early 1990s, many firms have come to rely on large, networked communities of

[10] Many regions have experimented with providing such resources, with decidedly mixed results. For a national survey of such efforts in biotechnology, see Cortright & Mayer (2002). For case studies of attempts to recreate Silicon Valley, see O'Mara (2005); Leslie & Kargon (1996); and Leslie (2001).

users to make suggestions about, test, or innovate on their products,[11] while others have been surprised when such communities arise (Walker 2012; Raymond 1998). Indeed, in some ways scholarship on user innovation and entrepreneurship is just catching up with attempts to leverage user innovations by the business community, government agencies, and university technology transfer offices.[12]

Early academic studies of users were conducted by scholars in management and in the history/sociology of technology (von Hippel 1988; Kline & Pinch 1996). Both sets of scholars pictured users as innovating only on technologies that were marketed by preexisting firms. That is, firms would sell a product that users identified as relevant to, but not adequately meeting, their needs, and then users would tinker with that product to adapt it to new uses or conditions. We and other scholars, however, have begun to expand the outlook of user studies to include users who invent whole new technologies, form new institutions and social formations to promote diffusion and innovation of those technologies, and found new firms and even *industries* based on those technologies.

What makes users innovative is, unsurprisingly, use. That is, in the course of interacting with their environment—in particular, with the technologies contained in that environment—users often come to see new or better ways of doing things which would be directly beneficial to them. Many users do not act on those insights, but a substantial number do. Studies conducted across various types of technologies find that 19–38 percent of users have, at some point, innovated on a technology for their own use. A recent study conducted in the United Kingdom finds that 6.2 percent of U.K. consumers report having engaged in innovation for their own use (von Hippel, de Jong, & Flowers 2012). The discrepancy between the 6.2 percent statistic and the range of 19–38 percent found in other studies may be due to a form of recall bias; it may be easier for individuals to recall having innovated when asked to think about their activities with a particular class of products than if asked generally.

However, technologies are not the only components of the environment with which innovative users interact. In many cases, *relationships with other users* also have been critical to user innovation and to users' decisions to found firms. For reasons we explicate more fully below, new users often seek out existing users for advice, while existing innovative users (and firms founded by those users) seek out other leading users to gain access to the latest innovations. Especially—but by no means only—when firms do not yet exist to market a technology, communities of users of that technology can become catalysts of innovation and entrepreneurship.

Our approach, therefore, privileges factors external to the individual in attempting to explain entrepreneurship, at least within the rather large and economically important class of user entrepreneurs. In particular, we focus on users' interactions with and

[11] Valuable and early insights on this topic often came from practitioners, see Kim (2000); Gabriel & Goldman (2005).

[12] For an example of the military leveraging user innovation among its personnel, see Lindsay (2010).

innovations on a technology, and their relationships with other users of that technology, as external factors that shape individuals' decisions whether or not to found a firm to market that technology. Unlike some approaches that examine the entrepreneur's external environment, however, we pay close attention to the ways the external environment changes over time, and especially to the ways in which potential entrepreneurs influence the environment that, in turn, shapes them. That is, we understand individual motivations (including motivations to found firms) to be *coproduced* with external factors such as the state of the technology and the complexity of the social structure in which the user is participating.[13]

IV. A Framework for Understanding How Users Develop and Diffuse Their Innovations

Coproduction, unfortunately, is a messy way of depicting innovative and entrepreneurial activities, even if it is faithful to the messiness of the phenomena. Even if we narrow our approach down to three components—a technology, a community of users centered on that technology, and individual users who are potential entrepreneurs—the co-evolution of those three components is still complicated enough to require at least a book-length description for just a single technology and user community.[14] To make our analysis simple enough for cross-case comparisons, therefore, we build upon a framework of four "modes" of user innovation and user community complexity developed in previous work (Shah & Mody 2013).

Our four modes are distinguished from each other by the characteristics of the social structure associated with the technology. Each mode fulfills a distinct purpose with respect to a technology's development and diffusion and serves the needs of a unique category of users. As a result, each of these modes will be constructed by users as necessary to develop and diffuse the technology in the direction that users prefer at the time—and therefore these nodes need not appear in any particular order. Like all frameworks, however, ours is an abstraction, albeit an empirically grounded one; reality is riddled with complexities.

We draw on established definitions used by technology scholars to differentiate between a technology and its constituent innovations: a "radical" innovation establishes the basis for a technology and is followed by a number of subsequent "conservative" (or "incremental") innovations that serve to improve and refine the technology (Nelson & Winter 1982; Hughes 1987; McKelvey 1996). It is useful to note that both "radical" and "conservative" innovations—that is to say, the first groundbreaking innovation that

[13] We take "coproduction" in the sense developed in the science and technology studies field, as exemplified by the chapters (particularly the introductory essay) in Jasanoff (2004).

[14] Of which there are many in the history of technology literature. Some interesting examples include Lucsko (2008); Akera (2007); and Smith Hughes (2011).

defines a new technology and subsequent follow-on innovations—tend to be developed in the inventor mode.

A. The Inventor Mode

In the inventor mode, there is almost no social structure to speak of: the technology's inventor and perhaps one or two very close associates compose the complete set of users of the technology. In probe microscopy, both the first successful probe microscope (the scanning tunneling microscope, or STM) and a failed precursor (the Topografiner) were invented by small groups located within large research organizations: for the STM, two PhD-level staff scientists (one senior and one junior) and two technicians at IBM's laboratory near Zurich in the early 1980s; for the Topografiner, one mid-career PhD-level staff scientist and one to two technicians at the US National Bureau of Standards in the late 1960s. In both cases, the inventors were able to secure resources from their employers by claiming that the microscope would contribute to those employers' objectives; however, the STM (and possibly the Topografiner) were intended primarily for their inventors' own use, and in both cases the inventions grew out of the inventors' prior use of related technologies. The dozens of later variants of the STM, such as the (more commercially important) atomic force microscope, were invented by similarly sized groups of academic, corporate, or government researchers; the majority of these variants were invented primarily for their inventors' own use. The size and organizational location of the groups that formed around user inventors in probe microscopy is very typical for the broader class of scientific instruments (with exceptions for so-called "Big Science" experiments such as observatories, particle accelerators, nuclear fission and fusion reactors, etc.).[15]

Similarly, the windsurfer was invented by Newman Darby, a Pennsylvania sailboat enthusiast and amateur boat builder, with help from his wife and brother-in-law (i.e., Darby would qualify as an "occasional inventor" unaffiliated with an organization related to the windsurfer). The majority of subsequent innovations made in windsurfing were also made by users under similar circumstances, that is, these user innovators were unaffiliated, occasional inventors, often working alongside close personal affiliates (usually friends rather than relatives). They were led to their inventions both by prior use of related technologies (e.g., surfboards, waterskis) and by a desire to personally use windsurfing equipment in a way that currently available products did not accommodate.

[15] Some examples of scientific user innovation (in circumstances where small, localized groups of users were networked into a wider, distributed community of users working on similar technologies) can be found in Kohler (1994); Reinhardt (2006); and Landecker (2007). Even in Big Science fields, many innovations originate in small groups embedded in a larger organization. For some examples, see McCray (2004); Hoddeson, Kolb, & Westfall (2008); Galison (1997).

In both probe microscopy and windsurfing we observed the interplay of equipment, technique, and need. For example, users' need or desire to use particular products for particular applications sometimes led them to alter their equipment. Those alterations in turn sometimes opened new possibilities in technique; for example, the conducting of aerial acrobatic tricks on a windsurf board. As users sought to hone and refine such new techniques, they sometimes altered their equipment further. Modifications in equipment, technique, or needs often drove subsequent modifications.

B. The Community Mode

In the community mode, a small number (up to a few dozen) of users—whom we call "modifiers"—have heard about and then replicated an invention for themselves, often after establishing contact with the inventor. The transition to a true "community" mode comes when these modifiers have begun to innovate on the original technology (thereby becoming user innovators) and have formed connections among themselves (rather than just being connected to the inventor). At that point, improvements to the technology can move rapidly among modifiers, often through one-to-many modes of communication, and innovations can be taken up, tested, and discarded or retained at an accelerating pace.

In transitioning into the community mode, inventors and modifiers often make use of preexisting organizations and communication channels associated with related technologies or potential applications of the technology. The inventors of the STM recruited modifiers, for instance, by publishing in journals and attending conferences aimed at physicists and electron microscopists, in the belief that those fields would be most receptive to their invention. Their success also persuaded IBM Research managers to incentivize other IBM groups to build STMs, which in turn led IBM's rivals (especially Bell Labs) to encourage their groups to build STMs. In windsurfing, Newman Darby published a description of his invention in *Popular Science*, which gradually led a few modifiers to copy his design and/or contact him for more details. However, it took almost a decade and the efforts of subsequent user innovators for a large and interconnected user community to form. We can see here several motivations for inventors to cultivate a community: a desire to improve the technology, the fame, or the prestige associated with publication in a forum such as *Physical Review Letters* or *Popular Science*, the emotional satisfaction of being taken seriously by a powerful organization such as IBM or an established association of one's peers such as the American Physical Society, and the excitement and enthusiasm associated with being part of the development of something new.

Once enough modifiers have been recruited, however, they and the inventors may find that preexisting organizations and institutions do not suffice for communicating information quickly enough regarding innovations to the technology. In both probe microscopy and windsurfing, users created new mechanisms for one-to-many communication and for copresence very soon after entering the community mode: probe microscopists started an annual international conference (with published proceedings), while windsurfing enthusiasts began holding informal competitions and distributing information through newsletters and, eventually, dedicated windsurfing magazines. Such new, technology-specific organizations and institutions support technology development and diffusion by enabling collective and cooperative work, and highlight a second motivation for inventors and modifiers to form a community: the pleasure of working closely, collaborating, and competing with other individuals who share one's dedication to a new technology. Over and over again, our interviewees mentioned the emotional satisfaction associated with spending time with other community members. That satisfaction derived from many sources: the opportunity to meet new and interesting people and to travel to interesting locales (early probe microscopy conferences took place in Cancun, the Austrian Alps, and Oxford; windsurfing competitions in Hawaii); the pleasures of demonstrating one's own innovations or particularly skillful use of the technology, as well as learning about others' innovations and uses; and the intellectual ferment of discussing new innovations and uses with other members of the community in an atmosphere in which new ideas flow easily.[16]

Many inventions do not enter the community mode. Creating a community is difficult, thankless work; for inventors, the community mode also has the drawback of diluting their control over the invention. Some inventors may wish to transition to the industry mode by starting firms and commercializing their ideas.[17] In some scientific communities, the desire to standardize measurements leads inventors to move quickly to the network exchange mode, in which a limited number of user-producers ("kitmakers" in our terminology) supply noncommercial versions of the technology to user-consumers ("kitters").[18] In probe microscopy and windsurfing, the inventors did foster the creation of user communities soon after they got their inventions to work. However, in probe microscopy at least, the inventors pointedly drew a contrast between their actions and those of inventors of other instruments (such as the field ion microscope) who had blocked development of strong user communities. That is, the inventors of the STM knew there was nothing inevitable about the community mode and made a conscious decision to cultivate a network of modifiers who would build their own versions of the instrument.

C. THE NETWORK EXCHANGE MODE

In the community mode, almost all community members are both users and producers of the technology, and new members generally build their own versions of the technology

[16] The relationship between innovation and emotional cohesion in small groups has been well documented by Parker & Hackett (2012).

[17] E.g., Sara Blakely, founder of Spanx, see *Sara Blakely*, FORBES (Mar. 2012), http://www.forbes.com/profile/sara-blakely/; or Mark Stadnyk, founder of MadStad Engineering and a vocal critic of the disadvantages conferred on user entrepreneurs by the U.S. patent system. See Lohr (2012).

[18] See Kohler (1994); Murray (2009).

before being recognized by existing members. Not everyone who wishes to use a new technology, however, also wishes to build it. In the absence of firms that sell the technology, such users must find someone who will build all or part of the technology for them. If that happens, then the user community will now include users who are not producers, and it will include a few producers who produce for someone other than themselves. We call this the "network exchange" mode.

Network exchange contains some features of both the industry and community modes, but it is qualitatively different from both. The network exchange mode, unlike the community mode, will not form unless the technology has reached a stage where it is sufficiently easy to replicate and, typically, sufficiently easy to use. However, no one participating in network exchange is able to live off of providing copies of the technology to new users, as those in the industry mode do, and no formal organizations are dedicated to providing copies to new users. Moreover, the version of the technology that is provided to new users is often an incomplete "kit" rather than a fully operational product: for that reason we refer to providers as "kitmakers" and their "customers" as "kitters." In probe microscopy, for instance, some kitmakers provided the physical apparatus but not the electronics, others provided the electronics but not the apparatus, and others provided control software, but not the electronics or the apparatus.

Network exchange further differs from full commercialization in that kitters do not necessarily pay cash for their kits. In probe microscopy, some kitters offered kitmakers access to interesting experimental materials, or to expertise in difficult sample-preparation techniques, or helped them break into journals and conferences that otherwise would have been difficult for them to access. In both probe microscopy and windsurfing, kitmakers sometimes provided kits out of a sense of obligation. As one windsurfer kitmaker put it, "People asked for copies of our stuff . . . friends, friends of friends, friends of friends of someone." In probe microscopy, kits were given to kitmakers' current and former postdoctoral fellows, to fellow employees of the same university or company, and to friends from college or graduate school. In both windsurfing and probe microscopy, cash gradually became a token of exchange, but in amounts below market value. Windsurfer kitmakers initially gave kits away for free, then (as the volume of requests increased) for an amount equivalent to the cost of materials, and finally (as their time became consumed with kitbuilding) for cost-plus amounts. In probe microscopy, a few kitmakers were graduate students who (either on their own initiative or at their advisers' request) sold cheap kits to their advisers' former students, collaborators, or other professional contacts—with goodwill from their advisers or potential employers making up the difference between the exchange price and market value.

D. THE COMMERCIAL MODE

The most studied and most familiar of our modes is, of course, the one in which firms exist to sell products to consumers who do not have the time, skill, and/or interest to build a technology for themselves. In this mode, new members of the user community are overwhelmingly consumers rather than producers, and consumers' relationship to producers is primarily transactional (unlike in the community or network exchange modes where producers and consumers often form, or have preexisting, long-standing relationships). One precondition of the commercial mode, therefore, is that the technology has developed in a direction that is attractive to consumers—it is reliable and user-friendly enough that the costs incurred in casual use do not outweigh the benefits.

As noted earlier, plenty of consumers still modify commercial products to meet their specific requirements. Indeed, firms can decide to market specifically to tinkering users. In probe microscopy, for instance, the dominant manufacturer (with approximately 50 percent market share) built very reliable "black-boxed" products which were difficult to modify extensively; other manufacturers therefore carved out niches by selling products that were more easily modified and appealed to customers with unusual or rapidly changing requirements. Almost all of the firms manufacturing windsurfing boards that were not founded by users sought to create one-design mentality in the sport; one-design is a racing method in which all boats share identical or very similar designs. Many user-founded firms, however, sold equipment and components that allowed owners to customize their boards and practice the sport in more creative ways.

In general, though, the commercial mode is associated with standardization of the design and use of the technology in order for firms to achieve economies of scale. In this mode, as well, firms often attempt to capture the innovation process, either by forming their own in-house R&D units or by forming alliances with leading innovative users. In both windsurfing and probe microscopy, bringing innovative users in-house or into alliances with firms significantly enhanced those firms' reputations in the larger user community.

E. Moving Backward, Forward, or Not at All

In the case of very novel innovations, we observe that these modes often appear in the order in which we presented them above: inventor, community, network exchange, and industry. This ordering is intuitively appealing in that it is the order of increasing social complexity on several dimensions: the number of types of actors involved increases, the absolute number of users increases, and the primary set of users served by each mode is increasingly unwilling to build copies of the innovation for themselves.[19] In addition, an innovation's functionality and usability tend to be refined as it progresses through modes in this direction. As a result, most entrepreneurs will find it easiest to commercialize an innovation that has progressed from the inventor to the community to the network exchange mode, as the innovation will be further developed, will have diffused further, and the value of the innovation to potential customers (and therefore to potential

[19] Identifying a singular, precise metric of complexity might be an interesting topic for future research.

entrepreneurs) will be more clear. However, an entrepreneur might also choose to commercialize an innovation that has not passed through these modes; that entrepreneur would then have to expend greater personal resources to develop both the innovation and the potential market for the innovation.

However, it is important to stress that our modes do not necessarily form a chronological sequence. Recall that each mode fulfills a distinct purpose with respect to an innovation's development and diffusion and serves the needs of a unique category of users. Most individual user innovations in probe microscopy, as well as the field itself, moved through all four modes in the order that we have presented them. Most—but not all—user-generated innovations in windsurfing moved through the four modes in the order presented; some user innovations made late in the product life cycle skipped either the community or network exchange modes, as innovators believed that there was an established market for the technology and—in a shocking turn of events—Darby's original design for the windsurfer was ostensibly copied and then streamlined by two entrepreneurs (not users) who quickly patented and commercialized the innovation.

Many other user-created innovations have taken other routes. As we have noted, some inventors have commercialized their inventions almost immediately upon using them to their satisfaction (thereby skipping the community and network exchange modes), while others have skipped straight to network exchange. Many technologies remain in the inventor, community, or network exchange modes for long periods (perhaps indefinitely) without proceeding to the commercial mode. This situation is very common in scientific instrumentation, where the total number of users may be small and where almost all users may wish to build the technology for themselves to meet their own specific requirements.

Technologies can also proceed "backward" from a more complex mode to a less complex mode. For instance, when all firms that market a particular technology cease doing so (e.g., because doing so is no longer profitable or because a more profitable alternative has appeared), the commercial mode collapses. If there is still interest in the technology, however, then its users may regroup into the network exchange or community modes. This has occurred with a few beloved technologies of the early PC era, including the TRS-80 personal computer and the Apple Newton PDA (Muñiz & Schau 2005; Lindsay 1997). This pattern is also arguably observable in many hobbyist technologies, such as knitting or woodworking, where the pleasures of interaction with other users and of making something for oneself motivate users to form communities that exclude manufacturers of the technology (though firms that sell tools such as saws or materials such as yarn may still be incorporated into the community) (Maines 2009).

In other cases, a technology may be taken up in more than one mode simultaneously. This pattern was seen repeatedly in both probe microscopy and windsurfing. For instance, in probe microscopy a large number of distinct variants were invented. Some users (e.g., life scientists) perceived disincentives to use anything other than commercial, off-the-shelf instruments, while other users (e.g., physicists) perceived disincentives to use anything other than largely home-built instruments. Most users—"consumers"—were best served by the commercial mode, in which firms sold them instruments that they could use and modify modestly. A substantial minority of users, however, continued to invent variants and to cultivate small subcommunities of modifiers who would innovate on those variants. In a few cases, firms encouraged their employees to participate in these parallel user communities in order to maintain awareness of (and expertise in) these variants and to commercialize them when the technology and market potential had matured sufficiently. In some cases, when existing firms declined to commercialize a variant, that variant's inventors or modifiers were driven to found new firms.[20]

V. Entrepreneurship in Context: How Users' Technological and Organizational Activities Give Rise to Entrepreneurship

We are now able to examine more closely how user innovation—in technology and organization—can lead to entrepreneurship. While firm formation is most typical of the commercial mode, we find that all four modes possess unique characteristics that can foster (or hinder) entrepreneurship. We find that the experience of participation in earlier modes provides some individuals with the skills and motivations necessary for successful entrepreneurship.

A. Entrepreneurship Arising from the Inventor Mode

In the cases we have examined, there does not seem to be a direct link between invention of an altogether new technology (as opposed to innovation on an existing technology) and entrepreneurship in that technological category. In probe microscopy, the initial inventors of the scanning tunneling microscope, its precursor (the Topografiner), and the STM's most important variant (the atomic force microscope) all remained with their original employers (Stanford, IBM, and the Bureau of Standards), and none showed any interest in persuading those employers to market their inventions. The inventor of the windsurfer, Newman Darby, halfheartedly attempted to found a firm, but found little success.

Based on our findings and knowledge of the actions of user entrepreneurs in other fields, we hypothesize a few conditions that would encourage the inventors of an *altogether new technology* to become entrepreneurs:

- The inventor's use of the technology must be so satisfying and so evidently not specific to the inventor's own needs or personality that the inventor could imagine others benefiting from the invention. This happens frequently when a technology or the context in which it is to be used is well established, and therefore

[20] For an extended description of user innovation and entrepreneurship in probe microscopy, see Mody (2011).

supporting institutions and a market for the technology exist (or can be created by the entrepreneur) and the entrepreneur can draw support and/or resources from these sources. Many examples of novel medical devices fit in this category.[21]

- The invention should be complex enough or have sufficient value added to its constituent components that other users will find it more attractive to buy it rather than make their own. Note that this condition may require significant adaptation from the original form of the invention—in which case the inventor may spend a significant amount of time between inventing and marketing the product and/or may seek a transition to the community mode (in order to access others' innovations on the technology) prior to founding a firm.
- Inventors who do not form the *first* firms to commercialize their inventions may view those firms as inducements to found their own firms if they feel the initial firms have not commercialized the technology properly or have not given the inventor sufficient credit or monetary reward, or if they see their status as the inventor as enabling them to capture market share from the initial firms.
- Inventors' experience with inventing and/or commercializing prior technologies (or watching their technologies be commercialized by someone else) may confer expertise or insight that will make entrepreneurship seem more feasible and/or rewarding with respect to a new technology they encounter.

This last circumstance was particularly notable in probe microscopy. One of the inventors of the STM, Gerd Binnig, went on to co-invent the atomic force microscope but refrained from commercializing either invention. However, he later went on to co-invent a probe-based data storage technology (the "millipede"), which IBM has tentatively sought to commercialize. Binnig later invented a number of software algorithms and founded a company, Definiens, to commercialize them.

The examples of other user innovators in probe microscopy serve to further underscore the aforementioned point that, while participation in the inventor mode is not necessarily linked to entrepreneurship, *repeated* participation in the inventor mode (which often allows for observation of the commercial process, its requirements, and its benefits—even if across different technologies) appears to be associated with entrepreneurship. In academic probe microscopy, those professors who either founded or allied with the first generation of firms were serial inventors, most of whom had some prior experience commercializing their ideas. Professors who invented probe microscope variants but had little prior inventing or entrepreneurial experience almost uniformly allowed their inventions to be commercialized by other parties. In several prominent cases, however, professors who did not found or ally closely with firms to commercialize their first inventions did do so after their second or third inventions.

[21] See, for instance, the case studies of several new medical imaging technologies in Blume (1992).

The cases of innovative probe microscopists embedded within firms further substantiate this pattern, although, in these cases, little commercialization occurred. The sole probe microscope variant that IBM commercialized—the SXM—was invented by an IBM scientist, Kumar Wickramasinghe, who had previously invented several other probe microscopes which neither he nor IBM had commercialized. Other corporate researchers (at IBM, Bell Labs, and Intel) who invented only one probe microscope variant did not pursue commercialization either by themselves or through their employers; instead, they waited for their inventions to be commercialized by third parties.

B. Entrepreneurship Arising from the Community Mode

In the community mode, many more individuals are innovating on the technology and rapidly communicating those innovations to one another than in the inventor mode. Even the most astute creators of altogether new technologies cannot consider every possible improvement to their inventions; indeed, they may neglect or actively resist even obvious improvements. In probe microscopy, for instance, the initial inventors of the STM were reluctant to computerize control of the microscope, whereas most of the first modifiers in the community mode saw computerization as a much-needed addition. In windsurfing, Darby did not envision a need for footstraps to help the rider remain on the board; once a windsurfing community took root, almost ten years after Darby's original invention, members of that community very rapidly added footstraps to the windsurfing board.

In both probe microscopy and windsurfing, subsequent user innovators who participated in the community mode were significantly more likely to found firms or to encourage others to commercialize their innovations than were the technology's original inventors. These user innovators have no chance to gain prestige by reinventing the technology; instead their claim to status in the community is secured by adapting it to a new use or by making it more powerful or easier to use. Improvements to the usability of a technology are closely linked to the commercial potential of the technology. In probe microscopy, most initial variants were extremely unreliable and were not regarded as commercializable; when innovations on those variants made them more reliable, however, commercialization generally followed quickly.

Similarly, adapting a technology to new uses can increase its market potential dramatically. In windsurfing, the original invention was only suitable for use on relatively placid lakes and rivers; subsequent user innovators adapted the technology for use on ocean waters with high wind and waves, thereby making its use more enjoyable and more marketable to existing users of surfboards. In probe microscopy, several subsequent user innovators were recruited by the initial inventors of the STM in the belief that they would adapt the STM for use in fields in which the inventors had little expertise (e.g., surface science or electrochemistry). These individuals therefore became expert in tailoring the technology for a new class of users—users who could become a potential market for a commercial version of the technology.

As mentioned before, the community mode is also associated with emotional satisfaction derived from rapid innovation and camaraderie with other innovating users. While the role of these emotive aspects of the community mode in fostering entrepreneurship is hard to measure, we observe that many of the most successful entrepreneurs in the fields we studied referred to the satisfactions of entrepreneurship in the same language they used to describe their earlier participation in the community mode. Entrepreneurs told us of the emotional rewards of learning the new skills associated with running a business, or their satisfaction in successfully competing against other entrepreneurs, or the pride they felt in making a quality product, or the camaraderie that bound the members of their start-up company. All of these are emotional rewards that are also typical of the community mode, where new skills must be learned, and where close relationships, involving both competition and collaboration, often develop among community members.

We hypothesize that, as long as these emotional rewards are forthcoming in the community mode, community members may be less likely to found firms. However, if the community mode enters a less exciting phase, community members may see entrepreneurship as a way to recover some of their earlier emotional satisfaction. It is perhaps telling that, in probe microscopy, the earliest entrepreneurs were people who had not generated rich affective bonds with other community members. The second generation of entrepreneurs, however, were people who had participated vigorously in the early community mode, but who viewed the later rapid growth of the community as diluting the affective rewards of membership (e.g., by making conferences too large and impersonal).

In addition, the affective ties among participants generated in the community mode can aid user innovators who later become entrepreneurs in that they may have readier access to their peers' innovations and a larger reserve of their peers' good will than entrepreneurs who do not engage in the community mode. Entrepreneurs can also make significant use of the new institutions and one-to-many communication mechanisms created during the community mode. These mechanisms allow entrepreneurs to gauge the market potential of the technology and then to advertise the debuts of their products. The competitions that brought together early participants in the windsurfing community, for instance, soon acquired corporate sponsorship, while the transition from windsurfing newsletters to windsurfing magazines was enabled by the emergence of firms that could advertise in those magazines. In probe microscopy, the first serious entrepreneur decided to found his firm only after attending an international STM conference to gauge the market; he then brought his first product to market somewhat before it was fully ready so that he could display it at the next year's STM conference. His company then became one of the major sponsors of that conference in following years, as did competing firms.

C. Entrepreneurship Arising from the Network Exchange Mode

In this mode, we see a few actors come right up to the edge of entrepreneurship in its usual sense. The questions to be answered then are why, and what factors encourage them to cross or back away from that line? We observe that inducements toward or away from entrepreneurship in the network exchange mode depend heavily on actors' positions within a user community and the nature of their relationships forged with other users—reinforcing our view that social determinants are as important as intrinsic personality characteristics in determining entrepreneurship.

In windsurfing, the network exchange period lasted a very short time, yet it was critical in shaping the emergence of an industry in several ways. First, it accentuated distinctions among windsurfer builders that had begun to emerge in the community mode: only some modifiers received large volumes of requests for boards, and only those who were willing to become kitmakers received further requests. Modifiers who were willing to become kitmakers were then primed to become entrepreneurs: they had acquired experience building boards for others, they were visible to (and appreciated by) large numbers of current users who were willing to recommend them to potential users, and they were able to gauge the size of the market and even to roughly determine price points. Forming a firm became attractive as a way to devolve some of the burden of board-making onto others.

In probe microscopy, the network exchange mode lasted for a longer period, although it ran in parallel with the emergence of a robust commercial mode. That is, once firms began appearing in 1987, they commercialized variants that had already passed through the network exchange mode for two or three years. New variants, however, continued to be invented and to transition into network exchange; some variants were then commercialized, others were not. A few groups that gained reputations as particularly innovative modifiers in the community mode became kitmakers upon receiving large numbers of requests for copies of or access to their microscopes.

Two main types of network exchange were common in probe microscopy. In one, low-status individuals who had some close tie to a high-status person used that connection to make a little cash on the side by selling cheap copies of the technology. Several graduate students used their advisers' network of contacts in this way, as did a few technicians who worked for well-known corporate, government, or academic probe microscopists. This type of network exchange was almost always short-lived since kitmakers had other duties that were more pressing. This type of exchange generally did not, therefore, lead to firm formation.

In the second type, well-known (mostly academic) probe microscopists received large numbers of requests from other academic specialists who wanted to collaborate. These specialists were sometimes given all or part of a microscope, in return for which they contributed knowledge of how to prepare samples, the samples themselves, journal articles co-authored with the kitmaker, and access to or increased credibility with the specialists' home disciplines (e.g., biochemistry, geology, surface science, etc.). Members of the kitmakers' lab groups (their students, postdocs, and technicians) received feedback from kitters regarding how to make the microscope more user-friendly and more narrowly tuned to the needs of the kitters' disciplinary colleagues. In this way, feedback from kitters in the network exchange mode translated easily into adapting microscopes for new markets in the commercial mode. Network exchange preceded—and likely primed—kitmakers' interest in commercializing their microscopes. A few high-profile kitters founded firms themselves; several others encouraged their students and postdocs to found firms (and then joined those firms' boards); still others sought out new firms and persuaded them to sell commercial versions of the kitmakers' microscopes.

Thus, network exchange can lead both to a more marketable technology and to a more market-savvy kitmaker. However, network exchange can also hinder, or at least complicate, entrepreneurship. Property rights—to materials and intellectual output—can be blurry in the network exchange mode. Kitters and kitmakers sometimes make explicit trades, but more often the exchange is ill-defined. Certainly, scientific kitters are often not given explicit instructions as to how they may or may not use their kits. In the biotechnology industry, there are many famous examples of kitters who modified and then commercialized gifted biological materials or intellectual property without due regard for the kitmaker.[22] In some instances this mismatch between the property rights regimes of the network exchange and commercial modes has led to messy lawsuits.[23]

D. Entrepreneurship Arising from the Commercial Mode

Obviously, this is the mode for which there are many explanations already advanced for why entrepreneurs emerge. However, much less has been written about the benefits entrepreneurs and new firms can derive from their relationships with members of a user community and vice versa. Particularly early in the commercial mode, new firms may lag behind members of the user community in producing new innovations, while individuals in the user community may look to new firms as a source of revenue or resources. In windsurfing, diversifying firms who entered the industry often lagged behind user innovators in terms of innovation, as well as brand and image. A number of these firms sought to associate themselves with the user community to gain visibility. For example, some arranged photo shoots with prominent user innovators, asking the user innovators to place decals emblazoned with the company logo on the innovator's homemade equipment. In probe microscopy, start-ups formed alliances with users to gain access to innovations but also to accrue status, visibility, and credibility from those users. For instance, the dominant probe microscope manufacturer in the 1990s ran a famous advertising campaign called "We Have Science Covered" in which their microscope stood next to seven covers of the journal *Science* featuring cover images generated with the company's products. The articles in *Science* associated with those covers were authored by prominent members of the user community, and four of the articles were actually co-authored with employees of the company.

22 See Smith Hughes (2011); Jones (2005); Fortun (2008); Strasser (2011).

23 See Murray (2009); Swanson (2007).

From the other end, some prominent innovative users closely allied with start-up companies in part to generate royalties from licenses on their patents. However, users also benefited from alliances with firms in a variety of nonmonetary ways. Alliances boosted their productivity and profile in the probe microscopy community—they had access to free microscopes and ancillary equipment, including beta-tested equipment that was not yet on the market (and therefore not available to competing groups). Alliances also helped users shape the design of start-ups' products that they knew would eventually become their own lab equipment—thereby ensuring that their own requirements would find their way into the firm's products. Also, allying with a start-up was one way to increase the size of the research subfield in which a user was working, so that the user's work would gain wider acceptance—if more people could replicate and extend a user's experiments, the user's work would gain more citations. Finally, allying with or founding a start-up also led to employment for users' current and former lab group members—indeed, personnel trained by prominent users rose very high in several firms and a few have gone on to found second- and third-generation spin-off firms.

VI. Concluding Thoughts

Many of our current theories, practices, and policies privilege profit and status as explanations for what drives innovators and entrepreneurs. By showing that entrepreneurship can be rooted in creative, collective activities, we suggest that existing theories may not provide a complete picture of our innovation and industrial ecosystems. These findings, alongside the findings of other scholars, point to the importance of the commons as a seedbed for economic, cultural, and social development. In particular, the effects of policies influencing innovation and entrepreneurship—be they focused on intellectual property law (Heller & Eisenberg 1998; Lessig 2001; Benkler 2004), support for start-up firms, or education and training—on user innovators and commons of various sorts ought to be considered.[24]

In this chapter we have tried to show some ways that user innovation paves the way for successful firm formation and even industry creation. In particular, we have shown that the social structures created by users support the formation of skills, attitudes, and relationships that can later be translated into entrepreneurship. The specific structure and content of a particular mode—how complex it is and how mature its technology is—affects how and why its members approach entrepreneurship. Each of our four modes—inventor, community, network exchange, and industry—offers users a different path toward (or obstacles to) entrepreneurship.

[24] The other chapters in this book, as well as the work of Madison, Frischmann, and Strandburg, provide a glimpse at the various sorts of commons that so pervasively and quietly develop the technologies and cultural artifacts available to us (Madison, Frischmann, & Strandburg 2010).

Acknowledgments

The National Science Foundation (under Cooperative Agreement No. 0531184) and Alfred P. Sloan Foundation provided support for this work. Our work has benefited from interactions with Emily Cox, Pierre Mourad, Mary Tripsas, and participants at the Convening Cultural Commons workshop at New York University School of Law. We are grateful to the many innovators, community participants, and entrepreneurs who graciously shared their time and experiences.

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