4 Pioneering by Free Innovators

In chapter 1, I explained that the incentives and behaviors of innovators acting within the free innovation paradigm differ fundamentally from those of innovators acting within the producer innovation paradigm. As a consequence, innovation outcomes created within the two paradigms should also systematically differ. Indeed, identifying and clarifying such differences is a major value that the free innovation paradigm can provide to researchers, policymakers, and practitioners. In what follows, I illustrate this important matter with respect to innovation development. In chapter 5, I will do the same with respect to innovation diffusion.

The specific difference between paradigms that I will focus on is the pioneering role generally taken by free innovators in the case of new applications and markets, with producers following (Baldwin, Hienerth, and von Hippel 2006). I document this pattern and then explain changes in the rate of both free and producer innovation as a new field or application matures.

Why Free Innovators Pioneer

To understand the pioneering role of free innovators, recall from chapter 1 that producers generally expect to spread their design costs over many purchasers. However, to justify that expectation, producers need to be confident that many customers will in fact be interested in the product they plan to develop. They also need to be confident that they can somehow establish the monopoly rights needed to serve the market at a profitable price. In contrast, information about these things is irrelevant to individual free innovators. They care only about their own needs and their own self-rewards—matters that they understand firsthand.

Reliable information on the likely extent of demand generally does not exist at the beginnings of new applications and new markets where users are trying to do novel things—like experimenting with the first skateboards or with the first heart-lung machines. At that stage, markets are small and customers' needs are not clear. As a result, the information that a producer needs to determine whether acting on an innovation opportunity will be profitable is not available until well after the information that an individual innovator needs to determine the personal viability of that opportunity is available. This difference allows us to reason that free innovators will generally begin to innovate in new applications and new markets before producers do so (Baldwin, Hienerth, and von Hippel 2006).

Historical studies do support a pattern of free innovator pioneering. Many describe a sequence of events in which free innovator hobbyists enter new applications and markets ahead of producers in fields ranging from the development of the first aircraft (Meyer 2012), to the first personal computers (Levy 2010), and to the first personal 3D printers (de Bruijn 2010). Thus, Meyer documented that pioneering developers of the airplane were self-rewarding experimenters who freely shared their findings—free innovators—rather than early producers. "Early aeronautical experimenters were unusual, self-selected by their distinctive interest in the project of flight and their belief that they could contribute to it. They had an interest in the end goal. This helps explain why they would share their findings and innovations in clubs and journals and networks" (Meyer 2012, 7).

Pioneering by free innovators is also very visible in two quantitative studies that have explored the sources of innovation in new fields over time. I will briefly review the findings of those studies next.

Evidence of pioneering by free innovators in whitewater kayaking

The first of the two studies I will review involves innovation in equipment used in the sport of whitewater kayaking. Whitewater kayaking involves using specialized kayaks to maneuver in rough white water and also to perform acrobatic "moves" or "tricks" such as spins and flips. The sport began in about 1955 when a few adventurous kayakers began to develop methods of entering white water waves sideways or backward as a form of play. Soon, these "extreme paddlers" found one another and formed small communities to enjoy and develop the sport together. From those small beginnings, the sport of whitewater kayaking slowly grew to substantial size. In the mid 1970s there were only about 5,000 whitewater kayaking "enthusiasts" (frequent participants) in the United States (Taft 2001). By 2008 the sport had spread around the world and 1.2 million people were engaged in it, accounting for about 15 percent of all paddling activities (Outdoor Foundation 2009, 44). Expenditures by participants for gear and travel and other services reached hundreds of millions of dollars annually by 2009 (Outdoor Industry Foundation 2006; Outdoor Foundation 2009).

Hienerth (2006) and Hienerth, von Hippel, and Jensen (2014) studied the innovation history of whitewater kayaking from 1955 to 2010, carefully documenting the nature and source of innovations deemed “most important” by both expert kayakers and field historians. At the conclusion of this work, my colleagues and I had a sample of 108 important innovations that had been developed during four distinct phases in the sport’s innovation history.

In phase 1 (1955–1973), whitewater kayaking was originated by adventurous kayakers as was noted earlier, and the basic outlines of the sport were laid down by the kayakers themselves. Kayakers were also the only developers of important equipment innovations in phase 1, collectively developing fifty. Near the middle of phase 1, small producers began to enter to serve the nascent market with commercial versions of kayaker-developed innovations. The producers developed no important innovations during that phase.

In phase 2 (1974–2000), whitewater kayaking techniques and equipment continued to develop rapidly. During phase 2, kayakers developed thirty important innovations and producers developed ten. Among the important producer innovations was the first rotationally molded plastic kayak hulls. These were much sturdier than the fiberglass versions that both kayakers and producers had been making previously. They were an essential enabler as kayakers steadily learned how to maneuver and play in increasingly rough water.

In phase 3 (1980–1990), which coincided with the middle years of phase 2, a few highly skilled kayakers, and eventually about a thousand, departed from the main practices of the sport to develop a novel form of whitewater play that they called “squirtboating.” Squirtboating involved development of new maneuvers (“3D moves”) that were carried out partially underwater in “squirtboats” of novel design. Squirtboats have very little buoyancy and were only safe in the hands of expert paddlers. Kayakers were the only innovators in phase 3, collectively developing ten important innovations.

In phase 4 (2000–2010), squirtboating largely merged back into the mainstream of the sport as a result of general adoption of the "rodeo kayak" hull design developed by kayakers. The hull of a rodeo kayak has high buoyancy at the center of the boat but very low buoyancy at the ends, and enables even non-expert playboaters to perform many 3D moves such as forcing the bow or stern of the boat underwater and doing end-to-end flips. In phase 4, kayakers developed no important equipment innovations and producers developed four.

The pattern and the sources of important whitewater kayaking innovations just described are summarized graphically in figure 4.1. As can be seen, kayak users clearly were the innovation pioneers in the new sport, preceding producers by more than 20 years. Further, kayak users were clearly the dominant source of important innovations in the sport. Of the 108 most important equipment innovations, 87 percent were developed by kayak users; only 13 percent were developed by all kayak producers in aggregate (Hienerth, von Hippel, and Jensen 2014). As can also be seen in the figure, the rates of important innovations by both users and producers decreased over time (a matter I will return to shortly).

The pattern in whitewater kayaking clearly fits the argument made at the start of the chapter. In line with the premise of that argument,

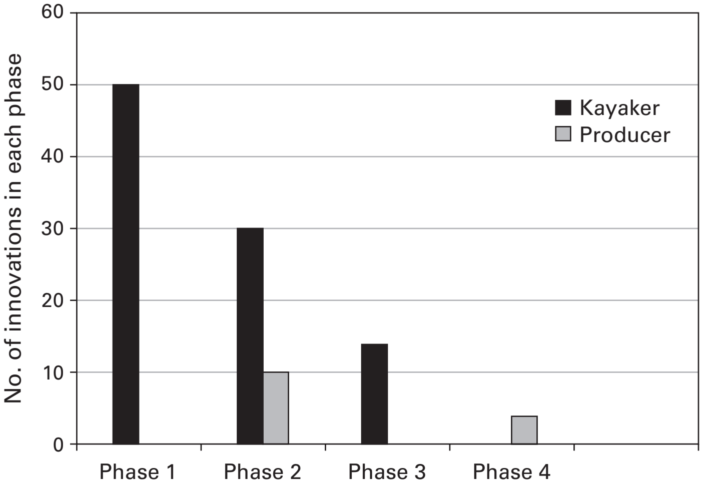

Figure 4.1
Source of important whitewater kayaking innovations over time. Source of data: Hienerth, von Hippel, and Jensen 2014, table 2.

innovating whitewater kayakers, when surveyed, reported being almost entirely motivated by self-rewards that could be obtained in full measure right from the start of the new sport. As can be seen in table 4.1, their self-reward came largely in the form of personal use of their kayaking innovations. They also freely shared their designs with peers and with producers (Baldwin, Hienerth, and von Hippel 2006; Hienerth, von Hippel, and Jensen 2014).

Table 4.1
Average motivations of household sector whitewater kayak equipment innovators.

Expected benefits from personal use	61%
Enjoyment from creating the innovation	17%
To help others (altruism)	10%
Learning from creating the innovation	8%
Other motives	2%
Potential profit from innovation sales	1%

Source*:* Hienerth, von Hippel, and Jensen 2014, table 6. Sample size: 201.

In contrast, producers are motivated by sales and profits. Clearly the small size of the potential market from the inception of the sport through the mid 1970s (there were only 5,000 enthusiast participants 20 years after the start of the sport, mostly designing and building boats to suit themselves) would have been less attractive to producers than was the large market of over a million participants that had emerged by 2010. Thus, in whitewater kayaking, the pattern of pioneering by kayakers—free user innovators—is clear and makes good economic sense.

Evidence of pioneering by scientists in scientific instruments

A second study shows the same clear pattern of user pioneering of new markets and applications. In this case the contrast is not between household sector free innovators and producers; it is between scientists employed by universities and firms and producers of scientific instruments. But the motivational distinction is the same: Scientists developed and improved novel instruments in order to use them in their scientific work, whereas producers developed novel instruments in order to sell them to many users.

William Riggs and I studied the sources and the timing of important innovations affecting two related types of instruments used in electron spectroscopy (Riggs and von Hippel 1994). Electron spectroscopy for chemical analysis (ESCA) and auger electron spectroscopy (AES) are both used to analyze the chemical compositions of solid surfaces (Riggs and Parker 1975; Joshi, Davis, and Palmberg 1975). In our 1994 study, Riggs and I identified 64 innovations judged to be important by both users and producers expert in these instrument types. The period of development studied began with the initial inventions in about 1953 and extended to 1983.

As can be seen in figure 4.2, the pattern of important innovations in ESCA and AES is very similar to that in whitewater kayaking. Scientists

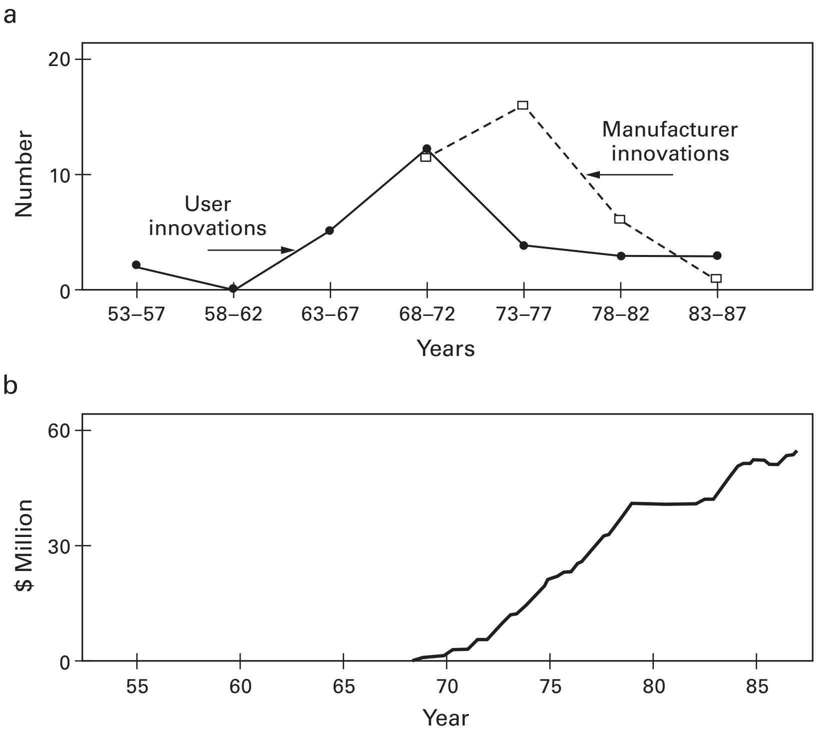

Figure 4.2
Source of important innovations in two types of scientific instruments over time. Graph a represents frequency of innovation; the first user innovations were developed around 1953, the first manufacturer innovations were commercialized around 1969. In graph b, the vertical axis represents millions of constant dollars, with a base period of 1982–84. Source: Riggs and von Hippel 1994, figure 2.

were the initial developers of both instrument types, and also of all early important improvements; producers only begin to innovate years later, with their first important innovations being commercialized in 1969. Also note that, just as in whitewater kayaking, the frequency with which both scientists and producers generated important innovations eventually declined, even though the combined sales of ESCA and AES instruments were rising (figure 4.2b).

The distinction between the innovation motives of scientists and producers is evidenced by a clear difference in the types of innovations they developed. As can be seen in table 4.2, scientists tended to develop innovations that enabled the instruments to do qualitatively new types of things for the first time. Such functions might have been of interest only to the innovators themselves, or they might also have been of interest to some additional fraction of the market. In contrast, manufacturers tended to develop innovations that made an instrument more convenient and more reliable in general—attributes of at least some interest to all potential customers. For example, scientist users were the first to modify the instruments to enable them to image and analyze magnetic domains at sub-microscopic scales, a capability of interest to only some users. In contrast, producers were the first to computerize instrument adjustments to improve ease of operation, a matter of interest to all users. Sensitivity, resolution, and accuracy improvements fall somewhere in the middle, as the data show. These types of improvements can be driven by scientists seeking to do specific new things with their instruments, or by producers applying their technical expertise to improve the products along known general dimensions of merit, such as accuracy (von Hippel 2005).

Table 4.2
Sources of scientific equipment innovations by nature of improvements effected

	Innovation developed by		
Type of improvement provided by innovation	User	Producer	Total (*n*)
New functional capability	82%	18%	17
Sensitivity, resolution, or accuracy improvement	48%	52%	23
Convenience or reliability improvement	13%	87%	24

Source*:* Riggs and von Hippel 1994, table 3. Sample size 64.

The difference in focus between scientist innovators and producer innovators can also be seen in the scientific vs. commercial importance of the innovations the two types of innovators developed. Riggs and I found that the scientific importance of scientist-developed innovations was on average significantly higher than that of producer-developed innovations ($p < .001$). However, the commercial importance of producer-developed innovations was on average significantly higher than that of scientist-developed innovations ($p < .01$).

How can we understand these patterns? I propose that the logic is identical to that discussed for the kayaking innovation study described earlier. Scientists, with their rewards based on the research value of the innovations to their own work and on the “scientific importance” of their developments, innovate first. They are not concerned with the potential size of a commercial market for their innovations. In contrast, producers wait until the nature, the scale, and the potential profitability of the market are clear before investing in innovation development. And when they do invest, producers tend to focus on developing innovations of interest to the entire market, such as convenience and reliability improvements, rather innovations of interest only to some segments of the market.

Why Do the Rates of Innovation by Both Free Innovators and Producer Innovators Decline?

We now understand why free innovators would be the ones to pioneer new markets and applications for use in the household sector. But what accounts for the decline in innovation frequency that is prominently visible in figures 4.1 and 4.2? As can be seen in the figures, this decline affects both user innovators and producer innovators, even as the markets increase in size. In contrast with pioneering, in other words, this effect applies to actors in both the free innovation paradigm and the producer innovation paradigm.

Baldwin, Hienerth, and I explained this pattern by arguing, first, that a new “design space” is opened up by the discovery of a new field or market (Baldwin, Hienerth, and von Hippel 2006). For example, the idea of intentionally engaging with rough white water in kayaks, as opposed to avoiding it as kayakers had historically done, was the creation of a new design space. This space contains all potential types of activities—not yet explored or even imagined at the time the new space is first perceived—that can be done in white water with manually powered kayaks. It also includes all possible designs of technique and equipment needed to realize them. However, any fixed design space has a limited number of valuable innovation opportunities within it. As time passes and search continues, it is reasonable that the valuable opportunities in the new design space will get progressively discovered and "mined out." The cost of searching for each of the increasingly rare undiscovered opportunities remaining will therefore rise, eventually making further searching unviable for innovators. This "mining out" is, my colleagues and I think, the reason why the number of innovations discovered in both whitewater kayaking and two types of scientific instruments declined with the passage of time.

Note, however, that in figures 4.1–4.2 we can see that the decline in the rate of producer innovation lags behind the decline in the rate of free or user innovation in both whitewater kayaking and scientific instruments. Why is this the case if the design spaces were in fact being mined out? The answer is that the steady rise in sales (shown for ESCA and AES instruments in figure 4.2b) made more and more innovation opportunities present in the design space financially viable for producers. Innovations of relatively smaller value to many people—the ones remaining as the space is mined out—can be justified only if there are many potential purchasers. In contrast, of course, the number of viable innovation opportunities in the design space does not increase for free innovators as the commercial market grows: their self-rewards are not affected by the size of the market.

Although "mining out" is a useful explanation for declining rates of innovation in our two cases, I caution that the effect exists only within a stable and even confining definition of a "legitimate" design space. For example, the rules of whitewater kayaking contests implicitly require that only manually propelled kayaks may be used—motors and motorboats are not allowed. If motors were allowed in the definition of the sport, the legitimate design space would clearly be larger, and "mining out" might take much longer. In the case of the two scientific instruments, the design space was defined to include only two instrument types with a common operating principle. If the design space had been widened to include *any* possible means to analyze the chemical composition of solid surfaces, it clearly would be much larger. Further, in cases in which there is no consensus on the boundaries of a design space (for example, today there is no apparent restriction on functions that people feel can be legitimately included in a smartphone), mining out is not a useful concept for understanding changes in the cost and rate of opportunity discovery and innovation development.

Finally, let me note that what was being mined out in our two case studies were opportunities for major innovations. Within any defined design space, opportunities also will exist at the level of what Hyysalo (2009) terms “micro innovations.” These may never be mined out. For example, each whitewater kayaker is probably frequently motivated to make subtle adjustments to his or her equipment to better fit his or her physical condition, specific method of executing a given maneuver, and so forth as these change. Similarly, users of scientific instruments will continuously find needs for micro innovations to adapt to small changes in experimental protocols, changes to other instruments also being used in an experiment being done, and so on. Opportunities such as these may continue to exist within even a fixed design space and may be acted upon by both free innovators and producer innovators indefinitely.

Discussion

Recall that a basic distinction between the free innovation paradigm and the producer innovation paradigm is the absence of compensated transactions in the former: Due to its self-rewarding nature, free innovation is viable without either establishing intellectual property rights or selling to others via transactions. This inbuilt difference does not make one paradigm “better” than the other. It simply means that the types of innovations done within the two paradigms can differ systematically.

As we have seen in this chapter, one systematic difference is that free innovators tend to enter a new field early, pioneering new applications and markets by serving their own needs. Through their efforts, whether there is a potentially profitable commercial market becomes clearer. If the activities of the free innovators do reveal commercial potential, producers will respond by entering later, and then will focus their innovation development efforts on general needs such as convenience and reliability. If no potentially profitable market is revealed, free innovators will be the only ones to enter the field, and any diffusion will be via free peer-to-peer transfer only (Hyysalo and Usenyuk 2015).

The focus of free innovators on pioneering means that, at the time of development, free innovations will tend to be less "commercially important" in terms of immediate profits for producers than innovations producers develop (Riggs and von Hippel 1994; Arora, Cohen, and Walsh 2015). This is because, as we have seen in this chapter, producers enter later than free user innovators, when new markets are larger. For example, the commercial value of initial aircraft designs developed by free innovator hobbyists was essentially nil relative to the very large markets for present-day aircraft designs (Meyer 2012). However, the profit metric of innovation importance clearly must be seen in the larger context of free innovator pioneering. For a new development or market to *become* commercially important, it must first be pioneered—and here, as we have seen, free innovators play a very important role.

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