

The Sociology of Innovation

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Technological innovation is a phenomenon that has been explored from a variety of perspectives, most prominently from the perspective of economics. Recently scholars from organizational and economic sociology have begun to explore innovation. In your view, does this research offer a coherent perspective on innovation? Of what value is an organizational and economic sociology perspective on innovation? In your essay, use your own ideas and readings from organization studies, economic sociology, and strategy and innovation.

INTRODUCTION

Car components like battery acid drainage troughs (Obstfeld, 2005), tetracycline (Coleman et al., 1966), sixth-generation *Pentium Pro* processors (Bothner, 2003), chain stores in the United States during the first half of the twentieth century (Rao, 1998), civil service reform (Tolbert and Zucker, 1983). What, besides the fact that prominent work by sociologists has treated each as an “innovation,” ties these examples together? The sociological literature has focused more on the latter examples of innovation in social structure than the former examples of product innovation which are recognizable as the subject of the mainstream economics literature on technological innovation. This is particularly true in terms of the study of the genesis, as opposed to the diffusion, of technological innovations. How can the much more established sociological literature on organizational innovation help us understand technological and product innovation?

As the examples above indicate, the economic and organization sociological study of to innovation is fractured and speaks to a wide variety of innovations. The term “innovation” is used by sociologists to refer to *new organizational forms* like chain stores, *new organizational processes* and routines like rule systems for appointing civil servants that are resistant to corruption, and *new products and services* like antibiotics and computer chips. Additionally, the focal innovation in each case can be considered in terms of different steps in an innovation process. Repeating a broader trope in the innovation literature, Roberts (1988) has shown that definitions at the core of the broader innovation literature describe innovations as incorporating both the creation of new ideas (i.e., *invention*) and the commercial success or diffusion of these ideas (i.e., *exploitation*). Adding one final level of complexity, innovations of one type facilitate, constrain, and provide the raw materials for innovations of other types and at different steps. For example, the creation and diffusion or innovative organizational structures both influence each other and affect technological product innovations.

In these ways, the sociological literature on innovation – like the mainstream economics-driven approaches to the phenomena – remains both broad and fractured. However, while these differences stand in the way of synthesis, cooperation, and coherence, they do not necessarily represent fundamental disagreements in the body of scholarship. Indeed, when considered in a framework that takes into account and structures the important differences laid out above, the sociological literature on innovation seems largely complementary in its basic findings and suggestions. Indeed, through this process of framework-building, weaknesses or “holes” in the literature, and possible means of connecting disparate streams, can be identified.

MAPPING THE SOCIOLOGY OF INNOVATION

The sociological approach to the study of innovation attempts to examine the way that social structure influences both the process and products of innovative activity. The fundamental sociological insight – that social structure influences behavior – can help explain innovation at multiple levels and at different stages of the innovation process. Additionally,

it can act as the first piece of a framework for integrating the broader sociological literature on innovation's component pieces. In so far as organizations engage in technological innovation, the study of innovation in terms of social routines and social structure provides a way to link sociological research on organizational process innovation to technological innovation. Innovations at the level of organizational forms structure innovations at the level of organizational routines and processes, and so forth, up or down the stack.

Type of Innovations

The mainstream – largely economic – study of innovation has been heavily influenced by Schumpeter's (1934) argument that innovative “recombinations” drive economic activity. Schumpeter's concept of recombinatorial innovation is open-ended and has been used widely in entrepreneurship (e.g., Baumol, 1990; Kirzner, 1997) as well as providing the definition of innovation for most economic and management approaches to the phenomena. That said, most research on innovation – both in economics and in sociology – has focused on a subset of technological innovations in the form of products, usually produced by firms.

In spite of sociologists' relative absence in the literature on technological innovation, Gilfillan's (1934) monograph on the *Sociology of Invention* and its companion volume on *Inventing the Ship* (1935) are often cited as seminal texts in the mainstream literature on innovation. Gilfillan defined innovations in terms of the technological artifacts of shipbuilding – from carved-out tree trunks to modern rudder designs. Schmookler (1966) – who Gilfillan sparred with on several less fundamental issues (e.g. Gilfillan, 1960; Schmookler, 1960) – used patents as an indicator of innovative activity and, as a result, adopted a very product-centric definition of innovation.¹ With a series of influential and seminal studies on the diffusion of innovations – including work by Ryan and Gross (1943) and Coleman et al. (1966) – the sociology literature pioneered, and has continued to be active in (Rogers, 1962; Strang and Soule, 1998), at least one part of the study of innovation of the type of that would be familiar with Gilfillan and Schmookler.

¹More abstract business method patents possible today were not allowed in the United States when Schmookler was engaged in research. The patent office often requested working physical instantiations of designs.

Among a series of its important contributions, Utterback and Abernathy's (1975) industry life-cycle model has been influential is its division of innovations into process and product types (also see, Utterback, 1997). But in offering this division as a way of explaining changing patterns of innovative activity and the quality and behavior of firms in technologically-driven, primarily manufacturing-focused, industries, Utterback and Abernathy also opened the door to a shifting focus from product innovation – where the previous innovation literature had been almost single-mindedly focused – to types innovation that touched upon the way in which products were made. The mainstream literature on technological innovation remains heavily influenced by this bipartite division and focused on both components as the object of research.

But process innovations that improve how organizations build products are not always technological in nature. Indeed, even in Utterback's (1997) examples from the automobile and other industries, key “technological” process innovations are often largely or even primarily managerial in nature. Conceived in this only slightly broader sense and rooted in the mainstream innovation research on process innovation, the sociological literature has much to say about of innovation in organizational processes and routines – if not always explicitly discussed in terms of a technological end-products.

And yet, sociologists also look at innovations at even more “macro” levels in the study of new organizational forms. Although increasingly distant from the core technologies of interest to Gilfillan and Schmookler, these new forms are still discussed in terms of innovation and, in sociological terms, are subject to similar pressures. For example, organizational sociologist Hayagreeva Rao titled his book about the role of social movements on the birth of new organizational forms “Market Rebels: How Activists Make or Break Radical Innovations” (2008). In his book, and in his other work with colleagues, Rao describes how once novel organizational forms like consumer watchdog organizations (1998) and chain stores (Ingram and Rao, 2004) are examples of innovation at the level of organizations themselves.

Not all of the sociological literature on new organizational forms is framed explicitly in terms of innovation. That said, processes and organizational forms can be understood as innovations in the basic Schumpeterian sense in that they act as novel recombinations de-

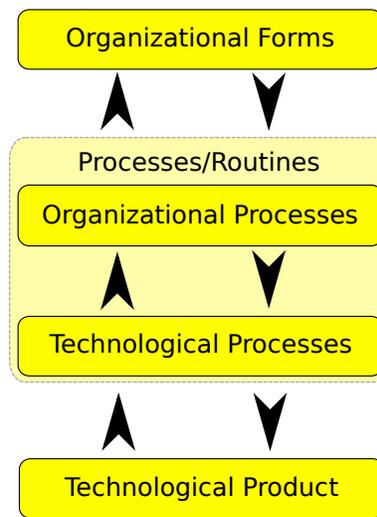


Figure 0.1: Basic description of the *types* of innovation as studied by sociologists.

signed to exploit available economic opportunities. In the broad economic sense, each is a form of technology. But even in the narrowest sense of technological innovation employed by classical innovation researchers, higher-order social process innovations remain influential through their interrelation to the technology that organizations produce through, and in, the resulting structures. Product innovations suggest particular process improvements which, in turn, imply particular organizational routines. In turn, these routines suggest particular organizational forms. In the sense that innovation at each level provides context for the more micro-level, this process works in reverse as well. A model showing this relationship is shown in Figure 0.1.

An example from the field of free, libre, and open source software (FLOSS) can demonstrate both the ontology proposed and the interrelated nature of the concepts:

The Linux kernel is a *technological product innovation* constructed through the cooperative work of a large number of firms and individuals which has diffused widely over the last 17 years over a series of commercial and non-commercial channels (DiBona et al., 1999) and which has been cited as highly innovative by researchers of technological innovation (e.g. von Hippel and von Krogh, 2003; Crowston et al., 2009).

As the Linux kernel development community has grown, managing contributions from a disparate group of developers has created the need for specialized tools to maintain a set of partially diverged versions from a variety of distributed contributors. To make this work more efficient, Linux project founder and lead developer Linus Torvalds created a *technological process innovation* in the form of the “Git” distributed revision control system to help maintain diverged “branches” of the Linux kernel over time.²

Due in part to this technological innovation, Linus and other members of the Linux development team have been able to introduce and support a series of innovative software development routines and *organizational process innovations* that, perhaps most famously, include releases that are more frequent and earlier than is possible in traditional software development (e.g., “release early, release often”) and primarily community-contributed debugging (Raymond, 1999).

Facilitated by this model, many different firms contribute to Linux. One long term effect of this has been the creation of the Linux Foundation to employ key developers, including Torvalds, in an institutionally independent space funded by a group of Linux’s major corporate stakeholders. O’Mahony and Bechky (2008) have argued that the Linux Foundation represents an innovation in *organizational form* that they call a “boundary organization” which was unprecedented in the software development industry.

Stages of the Innovation Process

In a retrospective article and literature review on the management of innovation, Roberts (1988) builds on previous work to define innovation as composed of both *invention* and *exploitation* – in Robert’s terms, “*Innovation = Invention + Exploitation.*” Although Roberts further breaks down the innovation process into four steps, his basic two-way split con-

²Details on Git and on the distributed source control model in general area available at the Git Homepage (<http://git-scm.com/>) and at the Wikipedia article on Git ([http://en.wikipedia.org/wiki/Git_\(software\)](http://en.wikipedia.org/wiki/Git_(software)))

tributes a parsimonious ontological frame through which to understand the broader sociological literature on innovation.

The literature on the sociology of science (e.g. Ben-David and Sullivan, 1975) has explored the impact of social structure on *invention* and the creation of new ideas and recombinations in science. Additionally, work on networks (e.g. Burt, 1991; Obstfeld, 2005) have explored the role that certain network structures play as antecedents of recombinatory activity in innovation. The literature streams on organization evolution, search, and learning each discuss the genesis of new organizational innovations.

A much larger group of sociologists have focused on what can be broadly conceived as the *exploitation* side of innovation. Alluded to already, Ryan and Gross (1943), Coleman et al. (1966), Tolbert and Zucker (1983), and many others have touched on how innovations diffuse through networks and institutional forces. Sociological work on entrepreneurship has described how structural qualities of organizational environments frame and shape the creation of new forms (Thornton, 1999). A variety of sociological theories including networks, fashion, and category pressures suggest mechanisms and antecedents for the diffusion and adoption of innovations at each of the levels described in the preceding section.

An Ontology of Sociological Approaches to Innovation

Table 0.1 displays a 3x2 matrix showing the intersections between *types of innovations* and the *stages of the innovation process* with a description of several of the major approaches that the sociological literature on innovation has pursued. As we move up the table, we move from “micro” processes related to particular technological innovations to more “macro” contextual elements. At the top of the table, innovations in organizational form are farthest away from the type of product and technological process innovation at the center of the more traditional innovation literature. That said, work in the organizational literature suggests that innovation success is closely associated with organizational factors and that organizational forms are likely to influence the success of particular technological innovations. Innovation studies have frequently shown the influence of high-level form-based variables, as opposed to simply issues of organizational processes, on innovation outcomes (e.g. Utterback and Suárez, 1993; Sørensen and Stuart, 2000).

| Innovation Type | Innovation Stage | |
|---------------------|---|---|
| | Invention | Exploitation |
| Organizational Form | Social movements frames | Legitimacy, Density, Niche partitioning (Ecology); Resource mobilization (Movements); Isomorphic pressures (Institutionalism) |
| Process/Routines | Evolution, Learning, Search, Dynamic Capabilities | Institutional pressures, etc. |
| Products | Social networks, Management Structure | Influence networks, marketing networks, fashion |

Table 0.1: A 3x2 matrix showing the intersections between *types of innovations* and the *stages of the innovation process* with a description of several of the major approaches that the sociological literature on innovation has pursued. Each of the six areas in the matrix lists antecedents of innovation from the sociological influential sociological explanations for the aspect of the innovation process for the type of innovation in question.

In a more specific sense, there is strong reason to believe that organizational form is more generally important to issues of technology. MacCormack et al. (2006, 2008) have built off the work of Baldwin and Clark (2000) and demonstrated support for the “mirroring hypotheses” and connected fundamental issues of organizational form to the modularity of technological artifacts produced. In both papers, the authors compare the more distributed form of open source software organization to centralized firm-based production. They find that FLOSS projects produce *much* more modular software.

Clark and Fujimoto (1991), Wheelwright and Clark (1992), and Sanderson and Uzumeri (1995) – just three relevant examples from the product development literature that speaks broadly to this point – have connected issues of organizational form and organizational processes to both the nature and the performance of technological innovations. Allen’s (1984) seminal work on the role of communication in innovation processes within organizations shows that reasonably small changes in organizational structure and processes can be associated with large differences in research and development and innovation performance.

Although I have worked to fill in each element of the matrix, each area is not equally

strongly represented in the sociological literature. Sociological research is far thinner, in general, in the *invention* column. At all levels, the sociological literature has focused more on explaining the antecedents of exploitation, and diffusion in particular, than on the creation of new recombinations. Sociologists have had more to say about isomorphism and why innovations spread than about where they come from in the first place. When sociologists do talk about the invention part of innovation, they tend to speak in terms of the creation of novel social structures and processes (the middle row) and not of technological innovation *per se*.

INNOVATION IN ORGANIZATIONAL FORMS

Prior to the the late nineties, Nelson and Winter's (1982) evolutionary economics model and its random and constrained variation focused explanations were the most influential explanation for the emergence of new organization forms. Recent sociological research on innovation in organizational forms has been largely defined in terms of the sociological study of social movements and in population ecology terms.

Explicitly attempting to offer a more sociological account, Rao (1998) leveraged the social movement literature on on framing (e.g. Snow et al., 1986; Benford and Snow, 2000) and described the emergence of new organizational forms as influenced by a process of multiple competing frames and conflict over frame legitimacy with the state and against alternative and competing frames. Finally, Rao suggests that there is a "cultural frame institutional perspective" that suggest that actors will creates new forms when they have sufficient resources (see McCarthy and Zald, 1977) as a way to realize an outcome they value highly.

Building off Rao's earlier article, Ingram and Rao (2004) frame their argument in both the social movements literature and the neo-institutional perspective. The authors looks at the way that formal laws influence the success of new forms and the interaction between different types of interest groups building off a resource mobilization perspective (McCarthy and Zald, 1977). In particular, they describe the way that chain stores were able to take advantage of cooperative agricultural interests and unions with whom they were

essentially willing to cut deals in order to bring additional resources to their own attempt to create legitimacy for their innovative form.

Ruef (2000) provides an ecological account of innovation at the level of organizational forms. In doing so, Ruef introduces the concept of an *organizational community* which, as he defines it, can be thought of in ecological terms as a population of populations. In Ruef's empirical example, the community is health care and he considers the emergence of a series of new forms including HMOs. Ruef imports traditional ecological theories of density dependence, legitimacy and competition finds empirical support for this approach in his analysis. Up until a point, new forms are helped by the density of other forms within the community that are similar which tend to legitimate the identity of the new forms. After an inflection point, niches become saturated and tend to deter the appearance of new forms due to competition.

Rao explicitly suggests that his social movement provides an alternative account to Nelson and Winter's (1982) variation-based evolutionary account of new organizational forms. That said, both the social movement based literature and Ruef's "meta-ecological" approach offers are focused in how new forms become successfully established. Essentially, neither offers much beyond the basic evolutionary "random-walk" models in terms of what influences the invention or creation of new organizational forms. Rao comes closest, perhaps, in his use of social movements frames to explain the sources of new forms and in the detailed account of how the specifics of the consumer watchdog organizations organizational form is negotiated through a series of political interactions in the organizational environment over a half-century.

However, this frame-based explanation only serves to pass the buck. If the innovative organization forms we are interested in are possible because of the creation of a new frame that has made it possible, we have simply assigned a new name to the recombinations we care about. If new organizations are the product of new frames, we are left asking how new frames are created. Ruef is no better in this regard. Ecological accounts often criticized for selection-based mechanisms that often offer thin explanation for the source of variation and novelty and Ruef's "meta-ecological" account is no exception in this regard.

In the exploitation column, both perspectives offer rich sets of antecedents for innovation in organizational forms. Ingram and Rao (2004) paint a detailed picture of how the successful establishment of an innovative form is contingent on a set of political and institutional pressures. Ingram and Rao shows how strong coercive political pressure in the form of a U.S. Supreme Court case favoring chain stores served to legitimate and set the ground for the diffusion of the chain store form. Additionally, the authors leverage a resource mobilization literature to describe how chain stores used both unions and the agricultural lobby to create political pressure in favor of the legitimation of the form. In a way that speaks to the generalizable nature of the theory, Ruef can import most ecological explanations. Ruef offers empirical support for what is essentially a full density-dependence story.

INNOVATION IN ROUTINES AND PROCESSES

Major approaches to innovation in organizational routines and processes in the organization and economic sociological literature have focused on evolutionary accounts, organizational learning, search processes, and dynamic capabilities. Questions of the diffusion of new routines have, in turn, focused on institutional approaches.

Routines are described as organizational genes in Nelson and Winter's (1982) influential evolutionary model of economic change and of organizations. That said, Nelson and Winter's explanation for the creation of new routines is under-theorized in their text and largely limited in a short section on imitation and random variation. Nelson and Winter describe innovation in terms of the novel recombinations of organizational routines. Combinations of routines might be seen as leading to innovative organizational forms, to innovative technologies, or to new routines. The final idea is intriguing and the model of "genes-building-genes" goes beyond Nelson and Winter's treatment.

Organizational sociological accounts of routine or process-innovation have also focused on organizational learning based explanations. Departing from a purely Schumpeterian approach, Levitt and March (1988) argue that organizations invent new routines by encoding the outcome of particular experience into routines within the organization

that, in the future, provide a guide to behavior. Search-based model provided a related approach. March's (1991) exploration component of his influential exploration/exploitation model involves a search-based approach to the creation of new routines. The effect is a basic mutation or experimental, pattern-matching approach within a value landscape (e.g. Thomke et al., 1998) that has been influential in a large amount of follow-on work (e.g. Davis et al., 2009, and the work of variety of simulation based approaches).

Indeed, a parallel critique was leveled at the view of resources by the dynamic capabilities approach to organizational strategy. The resource-based view of the firm (RBV) suggests that firms can be treated as collections of resources; routines and processes are certainly one key example of the type of resources under consideration (Wernerfelt, 1984; Peteraf, 1993). Much of the RBV literature has focused on routines. This is particularly the case in Teece et al.'s (1997) description of *dynamic capabilities* as, "routines to make routines." Responding to a critique of Teece et al.'s definition of dynamic capabilities as tautological, Eisenhardt and Martin (2000) tie the concept of dynamic capabilities closely to concrete examples of routine-building routines that include product innovation, strategic decision-making, and alliancing. Barriers to the creation of new routines, in this sense, include what Levitt and March (1988) refer to as "competence traps" and what Cohen and Levinthal (1990) call "core rigidities."

Diffusion of new routines has been the explicit topic of neo-institutional approaches in organization sociology. Meyer and Rowan (1977) argue that the adoption of new routines is driven by "institutional myths" which act as rationalized process elements which firms adopt in order to achieve legitimacy and, through this process, to increase their survival prospects. DiMaggio and Powell (1983) build on this description to describe how isomorphism is driven by coercive forces from an organization's environment which might include government mandates or requests from a supplier, mimetic pressures driven by a organizations adopting forms in order to increase legitimacy, and normative isomorphism driven by the professions. Tolbert and Zucker (1983) describe the way that rational concerns drove the initial adoption of civil service reform routines followed by a process driven more by concerns of legitimacy.

These accounts do more than tell us that routines diffuse and are adopted. Tolbert and

Zucker paint a contingent description of how routine-based innovations “move.” Westphal et al. (1997) show how routines connected to Total Quality Management (TQM) diffused through networks contingent on institutional pressures. Zbaracki (1998) show how a diffused routines often involves substantive change to the “reality” of the routines in question. Zbaracki shows how, as firms adopted and exploited TQM, they dropped some components and changed others while maintaining a consistent rhetorical position. Zbaracki’s approach is consistent with the insight that the adoption of a process – considered in many other accounts as a process of diffusion with a receptive target – diffusion itself may involve the act of recombination and innovation.

The sociological literature is focused on understanding social structure. Because routines and processes *are* social structure, they have been the most thoroughly studied “row” in sociological accounts of innovation. Indeed, the broadest sociological approach to routine diffusion might include all of organizational sociology including work on category and status-based pressures. Fewer approaches are visible on the creation side. That said, organizational theory offers useful approaches in terms of evolution, learning, search, and dynamic capabilities that can explain the creation of new organizational processes through several models of recombination. These approaches, especially those from strategy, have already proved useful in terms of contextualizing and providing antecedents for more traditional forms of technological innovation.

On the one hand, new routines are the process innovations that will create new technological innovations. For example, Eisenhardt and Martin (2000) explicit offer product innovation as an example of a dynamic capabilities. Indeed, in its focus on routines to build technologies, the product development literature seems like a rich point to begin to connect the sociological obsession with routine-generation and diffusion to the more core concept of technological innovation. That said, content with innovation as an end-in-itself, product development has been largely eschewed by more purely organization and economic sociological approaches.

INNOVATION IN TECHNOLOGIES

Sociological research strictly on the antecedents of new technological innovation has been sparse. Obstfeld's (2005) work on the *tertius iungens* offers one influential and recent network-based explanation for the antecedents of recombinatorial activity. Working within the social network tradition, Obstfeld argues that brokers spanning structural holes can benefit not only from actively maintaining and exploiting two parties' separation (i.e., the *tertius iungens* orientation described first by Simmel (1964) and explored in much more depth using Burt's (1991) concept of structural holes) but also by introducing and facilitating ties between parties – a process he refers to as *tertius iungens*. Obstfeld uses empirical data from product development in a large automotive firm to show that joining may be particularly important to success in innovation because it opens the door to the assemblage of diverse collections of resources associated with Schumpeterian innovation. This strategy, Obstfeld argues, has indirect benefits by allowing the *iungens* to become more involved in resource allocation in the context of innovation.

Obstfeld's approach can be seen being influenced by a resource-based approach to innovation that treats social network as conduits for information necessary for innovation – i.e., as the “pipes” in Podolny (2001) terms. Hansen (1999), working once again in the context of product development, builds on a related network-based perspective with a framing based on Granovetter's (1973) concept of weak ties. Hansen shows that neither strong nor weak ties are particularly advantageous in a general sense – both have their benefits and drawbacks in terms of search and knowledge transfer and the creation of new technological innovations through recombination. Building explicitly on von Hippel's (1994) work on sticky information, Hansen shows that the benefit of weak ties is contingent on the complexity and the codified nature of the knowledge to be transferred across subunits. In other words, recombinations are contingent both on the nature of social networks and on the nature of the information being combined. Among other things, Hansen's basic finding points to a sociological and network based model of the antecedents of user innovation (von Hippel, 2005) based on network forms and the nature of the information being transferred, although it one that has remained largely unexplored to date.

Davis' (2009) work on product development in eight joint collaborative development projects between high technology firms describes managerial processes that can lead to an improved ability to create new technological innovations through collaborative development processes in an multi-organizational context. In particular, Davis shows how rotating leadership characterized by alternating decision control, fluctuating cascades of network activation, and zig-zagging relationship trajectories provides access to a wider variety of resources than is accessible through non-rotating firms, and which is associated with higher product development performance.

Although this literature on invention of product innovations has been reasonably sparse, primarily recent, and highly focused on information flow and social networks as the antecedents to recombination, the sociological literature on exploitation in terms of adoption and diffusion is, once again, both richer and more diverse. Although major sociological treatments of the exploitation and diffusion of technological product innovations also tends to be network-based, additional explanations based on fashion and category pressures also play an important role.

The most influential sociological work on the diffusion of innovations includes work by Ryan and Gross (1943) and later by Rogers (1962) on the diffusion of hybrid seed corn. Fundamental work on diffusion by Coleman et al. (1966) focused on the diffusion of the antibiotic tetracycline through social networks of physicians. More recent work reexamining Coleman et al.'s research suggests that marketing effects may explain away much of Coleman et al.'s network story (van den Bulte and Lilien, 2001). That said, this alternate explanation can also be seen as overlapping marketing and social networks and questions of the causal relationship between these two linger. Other work by van den Bulte and Lilien (2004) on the adoption of ATM by retail banks has suggested, and provided empirical support for, a two-stage diffusion model based on observability (which might be influenced by marketing) and by influence. Accounts by Bothner (2003) on the diffusion of the Pentium Pro have made network-based contingent on competitive context.

The literature on fashion, ranging back to Simmel (1957), provides another sociological account for the diffusion of innovations based largely on countervailing pressures toward imitation and differentiation. More recent work by Salganik et al. (2006) provides em-

empirical support for this model of fashion and faddishness using a music sharing site as an experimental setting and shows that the introduction of minimal information on others' behavior dominate more objective measures of quality at all but the extremes – the “best” songs are unlikely to be the least popular and the “worst” are unlikely to be the most popular but almost anything else is possible giving the extreme effect of strong trending behaviors. Using simulation models, Strang and Macy (2001) show that, given imitation and variation in performance, no intrinsic quality at all is necessary for faddish behavior to emerge.

Other sociological work has described the way in which the adoption, rather than the diffusion, of particular technologies is highly contingent on social structure. Barley's (1986) influential article on the adoption of CT scanners in two hospitals shows how the use of a single technological innovation can have radically different effects on social structure based on complex, and difficult or impossible to predict, interactions of the technology with the social context of a particular technological deployment. The paper is an example of the importance of sociological analysis in studies of innovation diffusion and the way that social structure introduces contingencies in the exploitation component of innovation more broadly.

Garud and Rappa's (1994) study of cochlear implants, and the authors' other work on the topic, provides a cognitive approach that bridges the development or invention of a technology with its adoption and diffusion. In particular Garud and Rappa uses data on the development and adoption of cochlear implants to argue for a model of technological development that is essentially a triangle of interactions between each of (a) the beliefs that researchers hold about what is and is not technologically feasible, (b) the innovations in question as the artifacts that these researchers and engineers produce and (c) the routines that both developers and audiences use for evaluating the artifacts.

CONCLUSION

The sociological literature on innovation is uneven and incoherent, but it is not without structure or connections. Indeed, structured as I have suggested, the disparate literature

can be seen as largely complementary. Innovation of one type or at one level can be seen as providing the context or structure for innovation of different types on different levels. In general, sociologists have focused on issues of exploitation and on the role of process and routine-based innovation. Future research would be well served to leverage this work, and the theories advanced in it, toward more studies of technological innovation *per se* and in more work on the invention component of innovation in general. This will also set the stage for more meaningful integration with the broader literature on innovation.

A number of the processes associated with the adoption of organizational routines and processes that include status-conformity (e.g. Phillips and Zuckerman, 2001) and category pressures (e.g. Zuckerman, 1999) seem like largely unrealized theoretical approaches in the literature on technological innovation. In the sociological literature, these have primarily been focused on the adoption of particular pieces of social structure. Although the product development literature, in particular, has drawn tight connections between this type of structure and technology innovation, these processes seem likely to also play a role in the diffusion of technologies themselves and provide a set of sociological theories that can both provide a broader sociological account of the processes of technological innovation in particular. In general, studies around the invention and creation of new routines seem like a rich source of theories for sociological accounts of the invention of technology that remain largely unexploited.

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