An Integrative Framework for Understanding the Innovation Ecosystem

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Abstract

In order to gain deeper understanding of how innovation contributes to economic prosperity, we offer an integrative framework, which consists of a theoretical model and a set of methodological guidelines. The theoretical model posits that diverse communities of people and organizations engage both the production and use of networks of innovations in an ecosystem. The methodological guidelines help researchers conduct the analysis of discourse about multiple innovations in multiple communities from multiple sources, exploiting the synergy between human and computational analyses. Taken together, the framework provides an integrative perspective that helps shift innovation research and policy making from the paradigm-drive, discipline-based orientation to a problem-driven, interdisciplinary orientation.

1. Introduction

In today's global economic crisis, *innovation* has once again gained widespread attention as something that brings us hope. Most economic recovery policies around the world favor innovation. These policies seem to be based on a broad consensus that innovation will help the economy recover and prosper (c.f., Romer 1986). However, numerous questions remain for much debate among policy makers and researchers: For instance, have we been under-investing or over-investing in innovations? Will more spending always lead to more innovations? What kind of innovations helps boost a nation's economy? In the United States, while President Obama said that the U.S. should become an "innovation economy," his administration has no coordinated innovation agenda (Lohr 2009). This situation to a great extent reflects the heated but inconclusive debate on innovation. Some argue that the U.S. is falling behind in investing in innovations (Atkinson and Andes 2009); others say that America is still the most innovative country (Kao 2009). Some lament that innovations have been outsourced offshore; others are confident that outsourcing will not compromise innovations at home (Bhidé 2008). Some propose to double federal funding for basic research in the near term; others contend that the supply of innovations from basic research far exceeds the capacity to use them and thus more investment should focus on the creative use of innovations (Bhidé 2008).

This on-going debate and the urgency in making policy choices call for "a deeper understanding of how innovation, in all its forms, contributes to economic growth" (Lohr 2008, p. BU3). Fortunately, to gain such understanding, the Science of Science and Innovation Policy (SciSIP) has recently emerged as a research field and guide for policy. However, SciSIP research faces serious theoretical and methodological barriers.

Theoretically, one stream of innovation research is primarily focused on the *production* of innovations. The other stream is mainly focused on the *use* of innovations. However, the two streams rarely converge to show the whole picture of innovation supply and demand, limiting the explicability and impacts of innovation theories. While the different foci may reflect traditional theoretical or disciplinary boundaries, *methodologically* speaking, both research streams lack longitudinal, comprehensive data about the whole picture of the innovation ecosystem and the tools for collecting and analyzing such large-scale data.

To overcome these theoretical and methodological barriers, in this paper, we offer an integrative framework for understanding the innovation ecosystem. The framework includes a theoretical model that combines insights from research on both the production and use of innovations. The framework also offers methodological guidelines for studying the innovation ecosystem. Taken together, the integrative framework will prove its utility in innovation research and practice. In what follows, we describe the theoretical model first and then the methodological guidelines.

2. Theoretical Model

We define an innovation as an idea, practice, or object that is perceived as new by an individual or other units of development and adoption. Apparently, we have borrowed Rogers' (2003) classic definition of innovation, but his definition is primarily concerned with the adoption and adopters of an innovation. As we will elaborate below, the focus on adoption and adopters is inadequate to account for the whole innovation ecosystem and hence we have added "development" to the definition. Both development and adoption, both developers and adopters are integral components of an innovation ecosystem. Accordingly, we are equally interested in the development of inventions (such as patents) as well as the adoption of new products and services based on the inventions. Using information and communication technology (ICT) as an illustrative field, some ICT innovations include utility computing, Web Services, Service-Oriented Architecture (SOA), virtualization, Web 2.0, wiki, blog, and cloud computing. Each of these innovations does not exist in isolation. Rather, innovations arise and evolve in networks.

2.1. Networks of Innovations

Our world is smart; it is made up of networks of innovations (Ogle 2007). An innovation network is a set of innovations that are interrelated with each other. Innovations are related in many ways. First, a broader innovation may be comprised of narrower, more specific innovations. For example, wiki and blog are specific innovations that epitomize the more general innovation Web 2.0. A special case of this type of relationship is the distinction between the *conceptual* form of an innovation and the *material* form of an innovation. The conceptual form of an innovation is the set of ideas and information used to describe the innovation and evaluate its consequences. For example, the idea underlying the Web Services innovation is that computing is delivered as services over the web (Hagel and Brown 2001). In contrast, the material form of an innovation refers to the existence of the innovation in the physical world, often as artifacts and practices. Continuing the previous example, the material form of the Web Services innovation includes the computer hardware and software that carry out various specific Web Services, projects to implement Web Services, training sessions for the end users of the services, organization- or industry-level standards for the services, and so on.

Second, innovations may be related because they represent the same core idea. For example, both cloud computing and utility computing are based on the idea that computing is provided as a public utility, despite the fact that cloud computing is more recent and more specific about web delivery. Third, although the relationship between cloud and utility computing may suggest a simple transition from the old to the new, innovations may compete with each other. On the one hand, different expressions of the same underlying idea may compete. For example, both PSA (professional services automation) and SPO (service process optimization) are competing labels for software innovations that streamline project-oriented work in knowledge-intensive organizations such as design firms and consultancies (Wang and Swanson 2007). On the other hand, different solutions to the same problem may also compete. For example, the utility model and the proprietary model of computing represent opposite, competing visions for computing, each model leads to very different innovations in computer science research, product development, and industrial structure. Fourth, different innovations may complement each other to solve the same problem or accomplish the same task. For example, SOA and virtualization offer the necessary architecture and technology for providing Web 2.0 applications.

As innovations are interrelated in a network, their evolutionary trajectories (including their popularities and capabilities) are interrelated too. It may be helpful to conceptualize networks of innovations as part of an ecosystem, where innovations can be likened to species in a competitive and symbiotic resource space (Wang 2009). Just like an arctic fox subsisting upon guillemot eggs and remains of seals killed by polar bears, innovations rely on the *attention* and *money* that people and organizations invest in their development and application.

As resources flow through an innovation network, the popularity and capability of innovations in the network changes over time. However, findings from the few previous studies on the relationship among innovations are inconsistent at best, and thus it is problematic to generalize from these studies. For instance, Wang's (2009) case study of ERP (enterprise resource planning) found the evidence that innovations closely related to ERP, such as CRM (customer relationship management) and SCM (supply chain management), competed for attention with ERP and their popularity, as measured by the volume of published discourse, was negatively correlated with that of ERP. In contrast, other studies have shown that when a particular innovation is activated, related innovations may be activated as well (Berger and Heath 2005; Fiske and Taylor 1991).

To better understand the dynamic relationships among networked innovations, we must examine the people and organizations who navigate in these networks. Recognizing the traditional separate treatments of the production and use of innovations in the innovation literature, we describe the production of innovations first and then the use of innovations.

2.2. Production of Innovations

Who produce innovations? Why and how do they produce innovations? These are the questions motivating a large stream of innovation research. Having reviewed this literature, Hage and Hollingsworth (2000) proposed six functional arenas (basic research, applied research, product development, production research, quality control, and commercialization), where various people and organizations engage in the production of innovations. In basic research, the underlying foundations of phenomena and observable facts are investigated through experiments or theory development. Applied research directs knowledge created from basic research to a specific practical aim. In product development, existing knowledge is drawn to create new products and services. Production research helps deign the process of manufacturing the new products or delivering the new services. Quality control aims to improve the quality of the product/service. And lastly, commercialization helps the new product/service reach its customers.

While these six arenas are presented in a sequential order, Hage and Hollingsworth (2000) reminded that the production of innovation is not always a linear process from basic science to product development. More recently, Bhidé (2008) argued that radical innovations may not begin in basic research, but occur in product development and commercialization, hence heavy investment in basic research may have been overrated. While this line of reasoning has broadened the traditional narrow emphasis on basic research to everyone involved in producing the innovations, this broader view of innovation production shows only half of the picture. Innovations must be used to realize their social and economic value (Edgerton 2007).

2.3. Use of Innovations

Another main thrust of innovation research is oriented in the use and users of innovations. Research on the diffusion of innovations (DOI) exemplifies this use-based perspective. Diffusion is the process by which the innovation spreads through certain communication channels in a social system. DOI Research has shown that the extent and rate of an innovation's diffusion depend on the attributes of the innovation, the innovativeness of the adopters, characteristics of the communication channels, and actions by the advocates of the innovation (Rogers 2003). Having recently reviewed the literature on ICT innovations applied in organizations, Fichman (2004) offered a summary: "organizations that are larger, more diverse, have greater technical expertise, possess supportive senior management, operate in more competitive contexts, and perceive the innovation as more beneficial and compatible, are more likely to adopt a larger number of innovations, to adopt them earlier, and to implement them more thoroughly" (p. 315).

The individual or organizational use of an innovation is the user's innovation process. In the context of ICT innovations, according to Swanson and Ramiller (2004), innovation is a journey that involves four core processes: comprehension, adoption, implementation, and assimilation. First, organizations collect and interpret information from their environments about the existence and basic idea of an innovation. Second, this comprehension effort informs organizations' decisions on whether to adopt the innovation, plus the articulation of supporting rationales. Third, where adoption is in fact pursued, implementation brings the innovation to life – hardware and software are installed, business processes are changed, users are trained, and so on. Finally, in due course the innovation becomes assimilated into routines in organizational work systems. To this four-process model, we have added "abandonment" as a plausible alternative to assimilation, where the users stop using the innovation.

One of the main criticisms of DOI research refers to the assumption that the supply of innovations is relatively unproblematic (Rogers 2003). However relatively, this assumption is hardly true, as implied by our brief review of the literature on innovation production. Therefore, a good opportunity to advance innovation research is to break down the artificial divide between innovation production and of use. In this spirit, we propose the notion of innovation community to unify the two separate research streams.

2.4. Innovation Community – New Form of Organizing Knowledge Creation and Diffusion

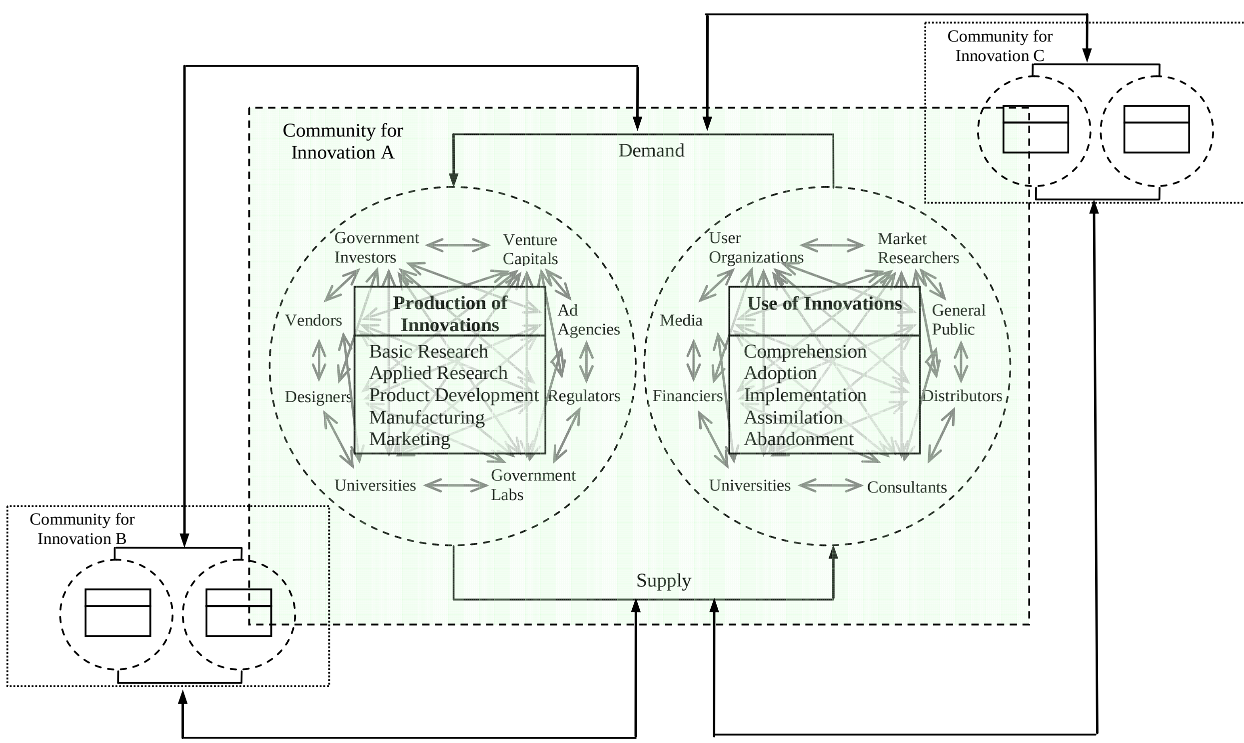
An innovation community is a set of organizations and people with interests in producing and/or using a specific innovation. Such a community emerges to make sense of the innovation and orchestrate material activities concerning the innovation. The collection of actors in the community evolves *dynamically*, as the collective attention to the innovation evolves. The community dissolves once the collective attention disappears. Hence activities in the community constitute a kind of "public project" that, once expired, takes the community with it. Members of an innovation community come from various sectors and share a focus on the innovation, but they are differentiated by the particular interests that motivate them. Their interests are indeed diverse: Scientists want to discover new phenomena or theories; engineers want to develop new devices and products; vendors want to sell their products; consultants want to sell their services; journalists want readers for their magazines and ads; prospective adopters want to make sense of the innovation and, ultimately, make sound choices. While diverse, these interests are also interdependent. For one thing, many community members are materially interdependent, participating in a mutually reliant value network made up of designers, suppliers, intermediaries, and customers. There is also a kind of interpretive interdependence, because each member's knowledge of the innovation is dependent on and subject to the "cycles of interpretation" taking place in the larger community (Swanson and Ramiller 1997). This interpretive interdependence points to learning as a community undertaking and community as a novel form of organizing knowledge creation and dissemination. The quality of community learning has implications to the success of the focal innovation.

The complexity of today's sciences and technologies and the complexity of the social and economic problems that innovations help to solve justify community as a new *organizational form* and as a unit of analysis for innovation research (Valdez and Lane 2008). An emerging stream of innovation research at the community level (e.g., Wang 2009; Wang and Ramiller 2004) will help eventually answer the key questions: How and why do innovations communities (comprising everyone producing and using innovations) form and evolve? What effects do the interactions in and across innovation communities have on the success of innovations?

2.5. Innovation Ecosystem

Summarizing, we use Figure 1 to illustrate the complex innovation ecosystem where networks of innovations and communities of people and organizations interact to produce and use the innovations. Specifically, the figure displays a network of three innovations A, B, C, and their associated communities. Lightly shaded in the center is the community for innovation A, constituted by diverse members engaging in two broad categories of activities: production and use of the innovation, represented by the two circles. Members actively interact with each other, as indicated by the arrows connecting them. The supply and demand determine the balance between production and use. It is possible for a member to engage in both types of activities. For example, universities may both develop and adopt innovations. Members can migrate from one activity category to another, from one innovation community to another, hence the dotted boundaries. As resources flow across innovation communities, production and use of innovation A may also depend on the supply and demand of its related innovations, as indicated by the double-headed arrows going across communities.

Figure 1: The Innovation Ecosystem



To gain deeper understanding of the innovation ecosystem, the integrative theoretical model we have proposed above can usefully be applied to innovation research. Only by considering both the production and use sides can one really understand the whole chains of activities in the innovation process and system. Meanwhile, such integrative view poses several methodological challenges, which we will address next.

3. Methodological Challenges and Guidelines

The integrative theoretical framework outlined above will significantly increase the scope and scale of innovation studies. The larger scope and scale bring both challenges and opportunities. In this section, we provide a set of guidelines for meeting the challenges and taking the opportunities.

3.1. Large and Diverse Scope of Study

As Figure 1 shows, each innovation community consists of a variety of actors involved in different activities related to the production and use of the innovation. Innovation researchers should examine these diverse actors and their diverse activities. However, one practical challenge is how to capture and study the phenomenon with such large and diverse scope. Despite the diversity, the actors and their activities in an innovation community are reflected and enabled in the on-going *discourse* about the innovation – what has been said and written about the innovation. Recent research in sociology, economics, management, and social informatics has examined innovations by directly analyzing discourse (Cheng et al. 2008).

Studying the innovation discourse has several advantages. Foremost, discourse provides a common denominator for observation. By examining innovations in communications, discourse analysis overcomes the difficulty in observing different kinds of actors and their activities in different circumstances. Second, thanks to advances in ICT, discourse data, especially in written form, are becoming easier to obtain. Third, discourse data are usually more reliable than data collected by asking informants to recall. Lastly, discourse data are rich in describing the context of innovation production and use, as opposed to the relatively simplistic data on the number of patents or adoptions. Taking all of this into account, we specify the first guideline:

Guidelines 1: Conduct discourse analysis to examine diverse actors and activities in the innovation communities and ecosystem.

Discourse has many outlets including advertisements, books, magazine articles, conference speeches, training materials, brochures, interview scripts, roundtable discussions, blogs, and so on. Each outlet serves a segment of an innovation community for a specific purpose. The social processes and system underlying the innovations manifest in multiple discourse outlets. Hence,

Guideline 2: Collect discourse data from multiple sources and triangulate the findings across the sources.

3.2. Large and Rich Scale of Study

The integrative theoretical model shown in Figure 1 also entails a multi-innovation and multi-community research design. A recent review has shown that studies of innovations often examine the production or use of one innovation in one community (Strang and Soule 1998). As previously argued, no innovation arises in isolation. Numerous innovations, related to each other to varying degrees, co-evolve in the innovation ecosystem. To understand the process and context in which innovations are developed and used, both the trees and the forest should be examined. Thus, *Guidelines 3: Study multiple innovations, multiple innovation communities, and the relationships among innovations, among communities, and between the innovations and communities.*

In any science or technology field, innovation studies have focused primarily on the boom periods of a few ultimately successful innovations, but not those innovations that never take off, and those experience a short heyday followed by a dramatic decline in popularity and legitimacy (Strang and Macy 2001). This bias severely limits theory-building and testing, because popular and successful innovations are rare instances and thus focusing on them risks overemphasizing the exceptions rather than the more abundant, less popular innovations, even though all innovations emerge, spread, and evolve in a competitive and symbiotic ecosystem. Therefore,

Guideline 4: Select innovations of all possible outcomes (e.g., successful, average, failed, and faddish) to study.

3.3. Computational Approach Scopes and Scales Up

The larger scope and scale of the research informed by the integrative theoretical model demands a new approach to discourse analysis. Traditionally, researchers faced a challenging trade-off between breadth and depth. On the other hand, qualitative case studies have offered deep insights (e.g., Munir and Phillips 2005; Wang and Swanson 2007). However, the process of acquiring and coding qualitative data is labor-intensive and each study can examine only one or very few innovations. As a result, it is problematic to attempt to generalize the findings of narrowly focused studies to explain the reality of innovation ecosystem. As we know, vibrant technology fields such as ICT are often populated with numerous innovations. Case studies lack the comparative scope and adequate scale necessary for one to understand the social dynamics of these vibrant fields. One the other hand, large-scale quantitative studies can examine many innovations (e.g., Bettencourta et al. 2006; Klavans and Boyack 2006). However, these quantitative studies typically use only thin observations such as counts of articles or citations and the observations are usually made in only one source – scholarly publications. These quantitative studies, though they are able to compare a larger number of innovations simultaneously, are unable to obtain the depth of the data required to understand the rich social structure and cognition that drive the production and use of innovations.

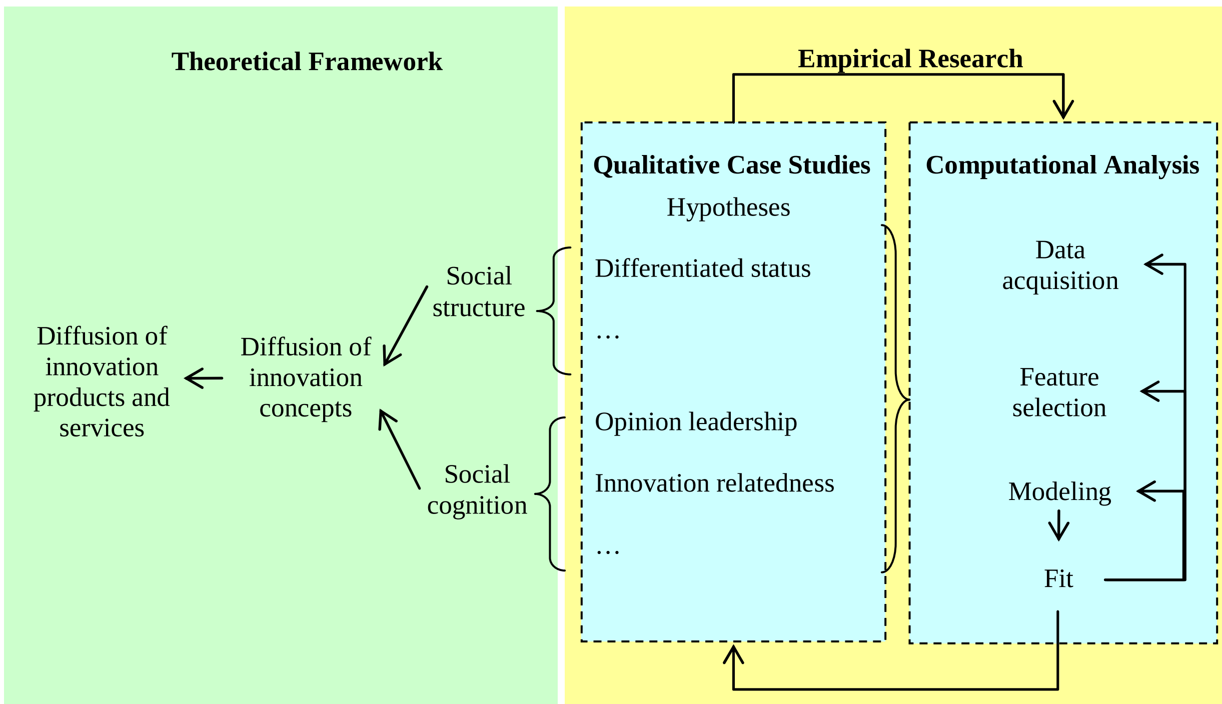
Innovation researchers balancing between breadth and depth may benefit from computational thinking (Wing 2006). Advances in computational linguistics and information retrieval now make it possible to analyze large corpora of text automatically, allowing us to capture far more factors for more innovations in longer period of time than was possible in previous studies, hence gaining understanding with both breadth and depth of the social dynamic underlying the innovation ecosystem. So,

Guideline 5: Take advantage of computational analysis of text.

Notwithstanding its obvious benefits, computational analysis relies on human interventions for its own development. Initially, it is useful to integrate the insights from intensive case studies into a theoretical model of the salient aspects of the innovation ecosystem. Then apply computational analysis to populate the model. Interpretations based on that model will next be used to guide refinement and enrichment of the computational analysis. For illustration, Figure 2 depicts such an iterative process in studying the diffusion of innovations. Guided by a broad theoretical framework (the left panel in Figure 2), researchers collect data and select features of the data to conduct a scalable computational analysis, in order to explore interesting hypotheses raised in previous case studies. Then feed the findings from computational analysis back to a new round of case studies, which will inspire another round of computational analysis. This "theory-based case-computation iterative inquiry" creates a new middle ground between today's richly analyzed but narrowly focused case studies and the presently available scalable but relatively shallow techniques, such as citation analysis. Hence,

Guideline 6: Computational analysis and case studies should inform each other in an interactive and iterative fashion.

Figure 2: Theory-Based Case-Computation Iterative Inquiry



4. Conclusion: Interdisciplinary Innovation in Innovation Research

Research in many fields has recently seen a major shift from the *paradigm-driven* orientation to *problem-driven* work. Today, faced with large-scale problems such as climate change, globalization, and economic and social development, researchers are increasingly taking interdisciplinary approaches to tackling complex problems, to which solutions are unlikely to come from only one field. The development and application of innovations nationally and globally is just one of the large-scale problems. The solution to the innovation problem is likely to be large-scale and integrate insights from multiple disciplines.

In this paper, we have proposed an integrative framework for understanding the innovation ecosystem. The theoretical model and methodological guidelines in the framework rely on and exemplifies interdisciplinary collaborations in at least two aspects. One is our balanced and inclusive emphasis on actors and activities related to both the production and use of innovations. The framework pieces together a holistic view of the innovation ecosystem. This integrative approach bridges disciplinary boundaries to facilitate understanding of the dynamic supply and demand of innovations. Traditional economic research focusing on innovation production does not require detailed data on use, nor does the sociological study of innovation use require much data on production. To answer fundamental questions about the innovation ecosystem, innovation research must capture and analyze the details of both production and use. The other aspect is the marriage between computational thinking and innovation policy studies, between state-of-the-art computational techniques with unique social science research questions. Just as the cyber-enabled ability to collect, visualize, and analyze data from a wide verity of sources has transformed many disciplines (Lane 2008), SciSIP research will also benefit from the transformative capability of cyberinfrastructure.

Historically, economic downturns often provided fertile ground for innovation. For example, many breakthrough ICT innovations such as the mini-computer, personal computer, web, and, more recently, social computing all emerged during economic difficult times. However, recessions do not produce innovations automatically. As we have demonstrated above, innovations are developed and applied by diverse communities of numerous people and organizations, interacting in a complex ecosystem. Useful insights from innovation research facilitate these interactions and foster innovations. The integrative framework proposed here is an innovation itself in innovation research. We hope that this interdisciplinary innovation sparks bright in this difficult economic time, fostering breakthrough innovations in research and practice soon and for many years to come.

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References

Atkinson, R. D., and Andes, S. M. "The Atlantic Century: Benchmarking EU & U.S. Innovation and Competitiveness," The information Technology and innovation Foundation, 2009.

Berger, J. A., and Heath, C. "Idea Habitats: How the Prevalence of Environmental Cues Influences the Success of Ideas," *Cognitive Science* (29:2), 2005, pp. 195-221.

Bettencourta, L. M. A., Cintron-Arias, A., Kaiser, D. I., and Castillo-Chavez "The Power of a Good Idea: Quantitative Modeling of the Spread of Ideas from Epidemiological Models," *Physica A* (364:2006), 2006, pp. 513-536.

Bhidé, A. *The Venturesome Economy: How Innovation Sustains Prosperity in a More Connected World*, Woodstock, Oxfordshire, Princeton, N.J., 2008.

Cheng, A.-S., Fleischmann, K. R., Wang, P., and Oard, D. W. "Advancing Social Science Research by Applying Computational Linguistics," in *Proceedings of the 2008 Annual Meeting of the American Society for Information Science and Technology*. Columbus, OH, 2008.

Edgerton, D. *The Shock of the Old: Technology and Global History since 1900*, Oxford University Press, New York, NY, 2007.

Fichman, R. G. "Going Beyond the Dominant Paradigm for Information Technology Innovation Research: Emerging Concepts and Methods," *Journal of the Association for Information Systems* (5:8), 2004, pp. 314-355.

Fiske, S. T., and Taylor, S. E. *Social Cognition*, McGraw-Hill, New York, 1991.

Hage, J., and Hollingsworth, J. R. "A Strategy for the Analysis of Idea Innovation Networks and Institutions," *Organization Studies* (21:5), 2000, pp. 971-1004.

Hagel, J., III, and Brown, J. S. "Your Next It Strategy," *Harvard Business Review* (79:9), 2001, pp. 105-113.

Kao, J. "Tapping the World's Innovation Hot Spots," *Harvard Business Review* (87:3), 2009, pp. 109-114.

Klavans, R., and Boyack, K. W. "Identifying a Better Measure of Relatedness for Mapping Science," *Journal of the American Society for Information Science and Technology* (57:2), 2006, pp. 251-263.

Lane, J. "Improvements and Future Challenges for the Research Infrastructure: Administrative Transaction Data," *National Science Foundation working paper*), 2008.

Lohr, S. "Do We Overrate Basic Research?" *New York Times*, November 30, 2008, pp. BU3.

Lohr, S. "In Innovation, U.S. Said to Be Losing Competitive Edge," *New York Times*, February 25, 2009, pp. B9.

Munir, K. A., and Phillips, N. "The Birth of the 'Kodak Moment': Institutional Entrepreneurship and the Adoption of New Technologies," *Organization Studies* (26:11), 2005, pp. 1665–1687.

Ogle, R. *Smart World: Breakthrough Creativity and the New Science of Ideas*, Harvard Business School Press, Boston, MA, 2007.

Rogers, E. M. *Diffusion of Innovations*, 5th ed., Free Press, New York, NY, 2003.

Romer, P. M. "Increasing Returns and Long-Run Growth," *Journal of Political Economy* (94:5), 1986, pp. 1002.

Strang, D., and Macy, M. W. "In Search of Excellence: Fads, Success Stories, and Adaptive Emulation," *American Journal of Sociology* (107:1), 2001, pp. 147-182.

Strang, D., and Soule, S. A. "Diffusion in Organizations and Social Movements: From Hybrid Corn to Poison Pills," in *Annual Review of Sociology*, J. Hagan, and K. S. Cook (Eds.), 24, Annual Reviews, Palo Alto, CA, 1998, pp. 265-290.

Swanson, E. B., and Ramiller, N. C. "The Organizing Vision in Information Systems Innovation," *Organization Science* (8:5), 1997, pp. 458-474.

Swanson, E. B., and Ramiller, N. C. "Innovating Mindfully with Information Technology," *MIS Quarterly* (28:4), 2004, pp. 553-583.

Valdez, B., and Lane, J. I. *The Science of Science Policy: A Federal Research Roadmap*, National Science and Technology Council, Washington DC, 2008.

Wang, P. "Popular Concepts Beyond Organizations: Exploring New Dimensions of Information Technology Innovations," *Journal of the Association for Information Systems* (10:2), 2009, pp. 1-30.

Wang, P., and Ramiller, N. C. "Community Learning in Information Technology Fashion," in *Proceedings of the Twenty-Fifth International Conference on Information Systems*, R. Agarwal, L. Kirsch, and J. DeGross (eds.). Washington, D.C., 2004, pp. 11-24.

Wang, P., and Swanson, E. B. "Launching Professional Services Automation: Institutional Entrepreneurship for Information Technology Innovations," *Information and Organization* (17:2), 2007, pp. 59-88.

Wing, J. M. "Computational Thinking," *Communications of the ACM* (49:3), 2006, pp. 33-35.